Center for Analysis and Information Services

Subarea Projections Model (SAM):

Allocating Employment and Population, Projecting Household Income, and Land Use Accounting

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SUBAREA PROJECTIONS MODEL (SAM): ALLOCATING EMPLOYMENT AND POPULATION PROJECTING HOUSEHOLD INCOME LAND USE ACCOUNTING

Association of Bay Area Governments

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OVERVIEW

Subarea Allocation Model (SAM) is designed to allocate employment, population, land use, and income projections for subcounty areas in the San Francisco Bay Region. In terms of geography, it covers the most detailed areas in ABAG's modelling system. Employment data includes six sectors; population data is presented by resident and total population, resident employment and number of households. SAM deals with six land use types. It projects mean household income and household income distribution.

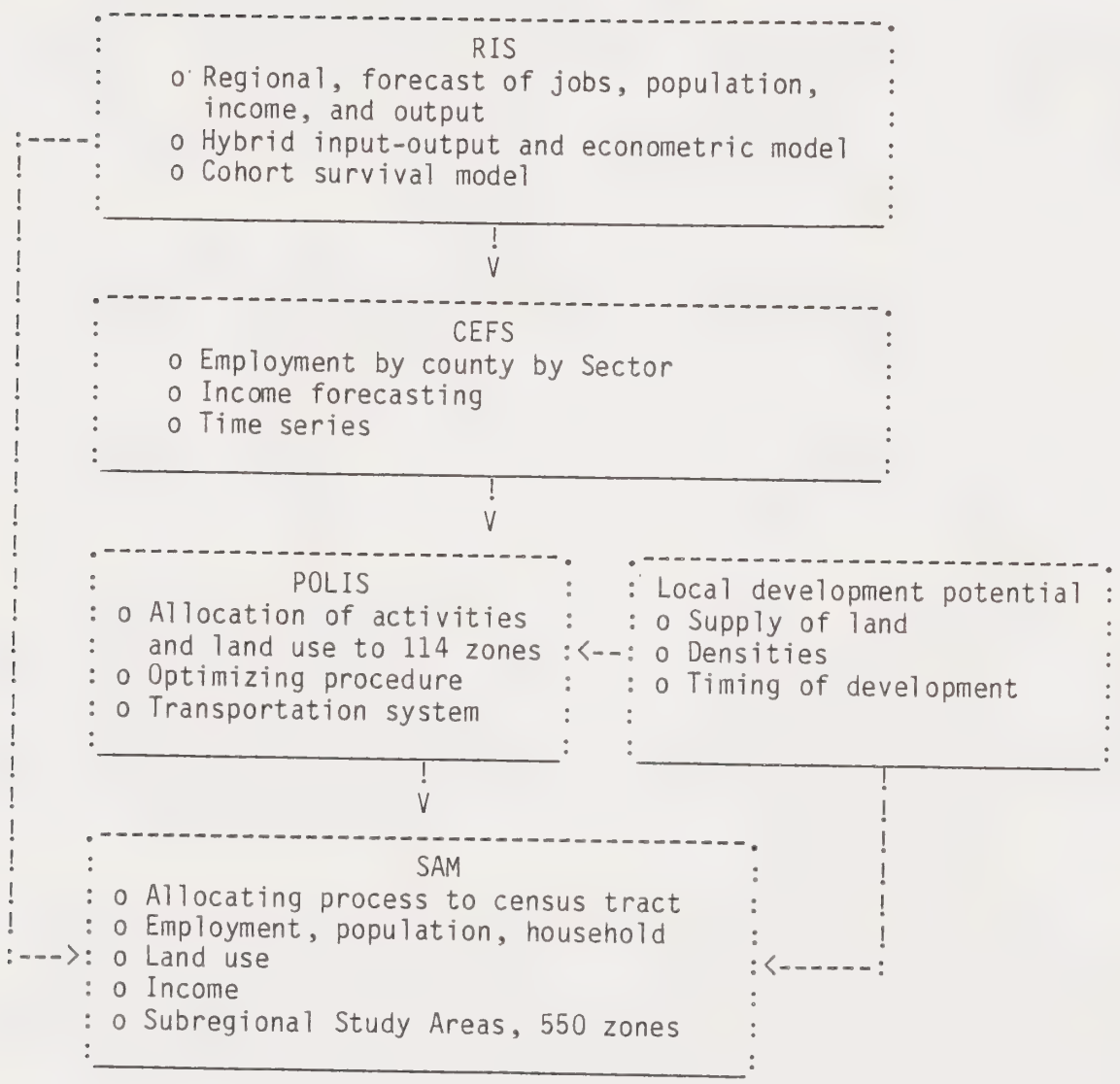
SAM is one component of ABAG's long-range projections system. The Regional Information System (RIS) produces regional economic, employment, demographic and energy projections (Brady and Yang, 1982). RIS generates employment estimates for 32 industry sectors. County Employment Forecasting System (CEFS) forecasts employment, income and population for counties based upon input from RIS. (Prastacos and Brady, 1984). The Projective Optimization Land use Information System (POLIS), in turn, allocates county totals to 114 superzones. Lastly, SAM allocates superzone statistics to 1209 census tracts. This region-county-superzone-tract projection process is repeated for each projection period. (See Figure 1.)

Subregional Study Areas (SRSA) and the Metropolitan Transportation Commission's (MTC) 550 traffic zones are two other subcounty geographic areas reported in SAM. SRSAs are delimited by the Local Area Formation Commission (LAFCO) sphere of influence boundaries for cities and aggregating census tracts within the sphere boundaries, including approximations of split tracts. The correspondence between SRSA and 1980 U.S. Census tracts is summarized in pages 227-232 in Projections 85 (ABAG, 1985). The correspondence between 550 zones and census tracts is available from MTC. Both SRSA and 550 zones are only reporting and reviewing units.

To ensure reasonableness, accuracy and consistency, statistics produced by SAM are carefully reviewed at each level and in each time period. ABAG's Projections Technical Advisory Committee (PTAC) and county, city, and town planning and related agencies conduct official reviews, commenting on regional, county, and/or SRSA projections. All population and employment projections are approved by the ABAG Executive Board and become the official long-term projections of the agency.

The following sections document the SAM design and its components. Household income projection, land use accounting model, and projection of single family households are discussed. In addition, a proposed procedure to improve the subarea projections to meet a specified development pattern is presented.

Figure 1 ABAG PROJECTIONS SYSTEM



ALLOCATING EMPLOYMENT AND POPULATION

The subarea projections model is designed to provide detailed economic and demographic information at the census tract level. The system is flexible and is designed to reflect areal variations and time fluctuations. It takes advantage of information on the most recent development patterns and trends on future growth.

SAM utilizes ABAG's extensive land data base derived from a survey of local development policies (ABAG, 1986). The survey data quantified current and future development potentials at the census tract level, containing detailed information on acreage, housing units and employment. It includes residential, "local-serving," and "basic" development types to define the available land supply.

The allocation model projects the following six employment sectors:

1. agriculture, forestry, and mining (SIC 01-14 excluding 074)
2. manufacturing (SIC 19-39)
3. wholesale (SIC 50, 51)
4. retail (SIC 52-59)
5. services (SIC 70-89, 074)
6. others (balance of SIC)

The first three sectors are considered "basic." The remaining three sectors are considered "local-serving" in the model.

SAM projects employment (at place of work); households; household population; household income; group quaraters population; employed residents; land acres developed by residential, commercial, and industrial activity; and street and highway acreages. It has an accounting system which keeps track of land consumed for development during any projection period.

The model requires the following files for its operation:

Input: number of census tracts in each of 114 superzone files
base year superzone file
forecast year superzone file
base year census tract file
forecast year development potential file

Output: forecast year census tract file

The layouts of these files are given in APPENDIX A.

The 1980 census tract file was constructed by merging (1) 1980 Census STF3 file for household and population data, (2) 1980 adjusted California Employment Development Department employment survey data, (3) ABAG 1980 estimated land use data, and (4) 1980-2005 development potential file.

There are 114 superzones in the ABAG region. These zones are aggregations of complete census tracts. Superzones were delineated to approximate relatively equal (in size), spatial population and employment subregions. The correspondence of the superzone and census tracts are given in APPENDIX B.

The employment and population allocation algorithm is specified as follows:

(1) Employment

$$E_{jk}^{t+1} = E_{jk}^{t} + \Delta E_{ik} \left(W_1 \frac{P_j^e}{\sum_j P_j^e} + W_2 \frac{E_{jk}^t}{\sum_j E_{jk}^t} \right)$$

Zonal basic (local-serving) employment increment is distributed according to the weighted census tract share of basic (local-serving) employment development potentials and weighted base year employment.

E_{jk}^{t+1} -- c.t. employment in census tract j, sector K, year t+1 (project year)

E_{jk}^{t} -- same as above but in year t (base year)

ΔE_{ik} -- zonal change of employment between base and forecast year, in zone i, sector k

P_j^e -- employment development potentials in census tract j; by basic and local-serving

W_1, W_2 -- weighting factor

(2) Land Use

$$L_{jk}^{t+1} = L_{jk}^{t} + \Delta L_{ik} \left(W_1 \frac{P_j^l}{\sum_j P_j^l} + W_2 \frac{L_{jk}^t}{\sum_j L_{jk}^t} \right)$$

Zonal basic (local-serving) land area increment is distributed according to the weighted census tract share of basic (local-serving) land development potentials and weighted base year acres.

L_{jk}^{t+1} -- c.t. land acre in census tract j, sector K, year t+1 (project year)

L_{jk}^{t} -- same as above but in year t (base year)

$\triangle L_{ik}$ -- zonal change of land acres between base and forecast year, in zone i, sector k

P_j^l -- land development potentials in census tract j; by basic (sectors 1-3) and local-serving (sectors 4-6)

(3) Occupied Dwelling Unit and Resident Population

$$HP_j^{t+1} = HP_j^t + \triangle HP_i \left(W_1 \frac{P_j^{HP}}{\sum_j P_j^{HP}} + W_2 \frac{HP_j^t}{\sum_j HP_j^t} \right)$$

Zonal occupied dwelling units (household population) are distributed according to the weighted census tract share of residential unit potentials and weighted base year unit.

HP_{jk}^{t+1} -- c.t. occupied dwelling units (residential population) in census tract j, year t+1 (project year)

HP_j^t -- same as above but in year t (base year)

$\triangle HP_i$ -- zonal change of occupied dwelling unit (residential population) between base and forecast year in zone i

P_j^{HP} -- housing unit development potentials in census tract j

(4) Group Quarters Population

$$GQP_j^{t+1} = GQP_j^t + \triangle GQP_i * \frac{GQP_j^t}{\sum_j GQP_j^t}$$

Base year census tract share of zonal group quarters population is used to allocate zonal change of group quarters population.

GQP_{jk}^{t+1} -- c.t. group quarters population in census tract j, year t+1 (project year)

GQP_j^t -- same as above but in year t (base year)

$\triangle GQP_i$ -- zonal change of group quarters population between base and forecast year in zone i

(5) Employed Resident

(a) find project year employed resident per dwelling unit

$$\frac{ER_j^{t+1}}{DU_j^{t+1}} = \frac{ER_j^t}{DU_j^t} * \frac{\frac{ER_i^{t+1}}{DU_i^{t+1}}}{\frac{ER_i^t}{DU_i^t}}$$

(b) derive the projected employed residents

$$ER_j^{t+1} = DU_j^{t+1} * \frac{ER_j^{t+1}}{DU_j^{t+1}}$$

(c) normalize ER_j^{t+1} so that

$$\sum_j ER_j^{t+1} = ER_i^{t+1}$$

ER -- employed residents
DU -- occupied dwelling units
i -- zone
j -- census tract
t -- base year
t+1 -- projection year

USE OF LOCAL POLICY SURVEY

In the above allocation algorithm, the use of development potentials, in terms of acreage, housing units, and potential employment from ABAG's local policy survey data, are unique. The survey quantified the type of land, the timing of its availability for development, and the housing unit potentials (ABAG, 1986). It aggregated the specific site data to census tracts for use in SAM. The survey specifies supply side conditions in which household and employment activities are to take place.

SAM uses development potentials as "attractors" for allocations of activities. At a subarea level (census tract), the greater the development potentials, the more the activities will be allocated there generally.

For review of subarea allocations, development potentials are used as the constraint for development of acreage, housing units, and employment. Outputs from SAM are compared with development potentials from the local policy survey.

HOUSEHOLD INCOME PROJECTION

Projections 85 made major changes in household income projections. Household mean income by census tract for years 1985, 1990, 1995, 2000 and 2005 was estimated using regression equations calibrated from the Projections 83 data base. Census tract mean income was then converted to ABAG's subregional study areas and reviewed and revised accordingly. Subregional area revisions were carried to the census tract data base and were reviewed again at this level of geography. At MTC's request, income projections were produced for each census tract for each of 17 income levels.

Using a gamma function provided by A. G. Wilson, mean household income was translated into income distribution by 17 income groups for year 2000 and 2005. 1980 U.S. Census income distribution was compared to the gamma function generated distribution. Trends of 1980-2000 and 1980-2005 trans-lated gamma distributions were used to derive final 2000 and 2005 distributions. distributions. A few census tracts were hand adjusted due to their special characteristics.

The following text will document the calibrated mean income projection regression equations, Wilson's gamma function and relevant statistics. Graphs of plotting on income distribution are provided.

Mean Income Projection

Mean household income is a variable produced by ABAG's projection project. The objective is to project mean household income in constant dollars by the smallest geographic area--1980 U.S. census tract--for every five-year period between 1985 and 2005. ABAG's subregional study area, MTC's 550 zone, and county were the other levels of geography where mean income was projected.

Due to limitations in the available data base, only cross sectional income projection regression analyses were conducted in Projections 83. It was strongly felt by staff that the result could be improved by incorporating time dimension into the analysis. Household growth over time was considered to be an important income predictor. Furthermore, it was felt that the results would improve by analyzing areas of relatively homogeneous characteristics. This was attempted by including county dummy variables in the Projections 83 regression analyses.

By using Projections 83 census tract files for 1980 to 2000, a set of pooled regression equations were calibrated for each of the nine Bay Area counties. A set of dummy variables representing area type were specified in the equation. The area type designation followed the results of the Social Area Analysis (ABAG, 1984) which classified each county in the San Francisco Bay Area into less than ten social areas by using factor analysis techniques.

A large number of potential independent variables were specified and calibrated. They included mean household income lagged one period, growth in households, employed residents, land use acres by type, and land density changes from the local policy survey. Transformations of these variables were specified too. Examples were employed residents per household in the current and previous period and proportions of non-residential land acres. Income growth rates for all periods by county, provided by Ray Brady (ABAG staff), were also specified in the equations. Each of the nine counties had mean income equations for years 1980, 1985, 1990, 1995, and 2000. The base year 1980 equation was used to calibrate the prediction equation for other years.

Results of the regression analyses are provided in the following tables. They are given by county order. Twenty-two census tracts, which are either 99 tracts or places having predominantly institutional population, were excluded from the regression sampling data. Independent variables are defined as follows:

ATX - area type dummy variables in a county

ATX = 1 if the census tract belongs to area X
ATX = 0 if the census tract does not belong to area X
where X = the social area in which the regression was performed.

ERHH - employed residents per household, i.e.,

$$\frac{\text{employed residents}}{\text{household}}$$

PNR - proportion of non-residential land uses, i.e.,

$$\frac{\text{industrial acres + commercial acres}}{\text{industrial acres + commercial acres + residential acres}}$$

DHH - difference of household unit between current and preceding period.

Table 1 MEAN HOUSEHOLD INCOME REGRESSION EQUATIONS BY COUNTY

Alameda County (N=284)

Variable	1980	1985	1990	1995	2000
AT2	-4,225	-4,304	-4,446	-4,584	-4,566
AT3	-9,783	-10,101	-10,462	-10,564	-10,874
AT4	-11,230	-11,527	-12,138	-12,214	-12,644
AT5	-13,687	-14,040	-14,693	-14,881	-15,409
AT6	-15,081	-15,418	-16,131	-16,256	-16,789
AT7	-16,959	-17,359	-18,244	-18,428	-19,237
ERHH	6,268	6,450	6,090	6,067	5,609
PNR	-4,646	-4,992	-5,163	-5,153	-5,075
DHH	0	0	0	1.21	1.75
Constant	25,850	26,675	28,094	28,352	29,520
R^2 x 100	72.03	71.21	71.43	71.83	72.32
F	89	85	86	78	80

Contra Costa County (N=151)

Variable	1980	1985	1990	1995	2000
AT2	-13,003	-13,300	-14,358	-14,460	-14,581
AT3	-21,327	-21,978	-22,994	-23,503	-23,536
AT4	-27,082	-27,740	-28,288	-28,983	-29,459
AT5	-22,705	-23,299	-23,880	-23,921	-24,354
AT6	-30,666	-31,296	-31,809	-32,614	-33,303
AT7	-32,946	-33,521	-33,678	-34,404	-34,281
ERHH	7,407	7,787	8,688	8,676	8,399
DHH	3.14	4.95	5.77	6.13	4.75
Constant	39,813	40,411	40,006	41,198	42,724
R^2 x 100	86.34	86.53	86.62	86.20	84.86
F	112	114	115	111	100

Marin County (N = 49)

Variable	1980	1985	1990	1995	2000
AT2	-12,418	-12,605	-13,339	-13,405	-13,833
AT3	-16,892	-17,167	-18,552	-18,883	-19,451
AT4	-20,349	-21,576	-23,064	-22,323	-22,808
AT5	-16,908	-18,275	-19,598	-20,145	-21,008
ERHH	18,521	17,291	17,751	17,934	18,593
PNR	-18,262	-18,362	-18,170	-19,268	-20,316
DHH	-6.53	-6.57	-0.38	-1.97	-4.23
Constant	21,803	24,887	25,921	26,525	27,140
R^2 x 100	72.47	72.33	71.32	70.97	71.07
F	15	15	15	14	14

Napa and Solano Counties (N = 79)

Variable	1980	1985	1990	1995	2000
AT2	-4,550	-5,282	-5,447	-5,449	-6,081
AT3	-7,760	-8,293	-7,927	-7,997	-8,776
AT4	-8,965	-9,243	-9,826	-10,029	-10,284
AT5	-10,898	-11,737	-11,246	-11,634	-12,398
PNR	-6,317	-7,560	-7,477	-7,404	-7,506
DHH	2.35	2.91	4.82	5.51	4.69
Constant	27,466	28,832	28,488	28,963	30,372
R^2 x 100	68.27	70.01	77.26	80.59	77.39
F	26	28	41	50	41

San Francisco (N = 145)

Variable	1980	1985	1990	1995	2000
AT2	-14,551	-14,908	-15,505	-15,805	-16,058
AT3	-17,235	-17,689	-18,394	-18,759	-19,061
AT4	-20,731	-21,249	-22,071	-22,536	-22,873
AT5	-23,586	-24,126	-25,059	-25,586	-26,037
AT6	-26,998	-27,616	-28,700	-29,571	-30,197
AT7	-27,819	-28,645	-29,467	-30,064	-30,686
PNR	-1,827	-1,832	-1,974	-1,991	-2,069
DHH	-5.78	-5.36	-2.78	-2.69	-1.72
Constant	40,910	41,841	43,414	44,407	45,185
R^2 x 100	65.77	65.59	65.58	65.49	65.42
F	33	32	32	32	32

San Mateo County (N - 143)

Variable	1980	1985	1990	1995	2000
AT2	-19,906	-19,704	-19,752	-20,011	-20,459
AT3	-27,134	-26,226	-26,131	-26,518	-27,286
AT4	-25,120	-22,890	-22,307	-22,502	-24,122
AT5	-28,819	-26,963	-27,189	-27,620	-28,655
AT6	-32,466	-30,752	-30,436	-30,922	-31,828
AT7	-35,343	-35,675	-35,823	-36,076	-35,985
ERHH	8,712	7,170	6,100	6,114	7,161
DHH	13.42	0	0	0	20
Constant	40,243	45,116	47,874	48,556	47,323
R^2 x 100	76.18	76.48	76.51	76.47	77.06
F	54	54	55	54	50

Santa Clara County (N = 257)

Variable	1980	1985	1990	1995	2000
AT2	-13,446	-13,748	-14,445	-14,995	-15,659
AT3	-13,697	-13,653	-14,376	-14,767	-15,464
AT4	-8,955	-9,119	-9,570	-10,167	-10,445
AT5	-15,607	-15,785	-16,625	-17,331	-17,665
AT6	-20,323	-20,417	-21,352	-22,117	-22,837
AT7	-18,284	-18,618	-19,466	-20,065	-20,911
AT8	-9,507	-9,397	-8,835	-6,744	-6,696
ERHH	13,399	13,663	13,976	13,414	14,145
PNR	-7,895	-8,372	-9,173	-9,374	-8,998
Constant	22,290	22,637	24,038	25,995	25,675
R^2 x 100	69.83	70.06	69.90	69.53	69.34
F	64	64	64	63	62

Sonoma County (N = 58)

Variable	1980	1985	1990	1995	2000
AT2	-7,047	-6,253	-5,813	-4,818	-4,777
AT3	-8,124	-7,637	-7,901	-6,304	-7,713
AT4	-7,293	-6,708	-6,380	-6,885	-5,107
AT5	-10,879	-10,095	-10,528	-8,992	-8,636
AT6	-7,255	-5,976	-5,986	-5,241	-5,470
ERHH	7,683	8,422	8,293	7,444	8,824
PNR	-8,263	-8,637	-8,422	-10,302	-13,390
DHH	3.23	6.84	6.09	3.21	2.11
Constant	19,666	18,179	18,513	20,394	20,007
R^2 x 100	64.49	75.32	67.84	60.17	45.95
F	11	19	13	9	5

As expected, lagged mean household income variables were predominantly significant. However, these variables precluded other candidate variables and greatly distorted the expected signs and beta values. It was decided not to include them.

Overall results are much improved from the Projections 83 income equations. R squares are more than doubled in most selected equations, ranging from low 0.6 to high 0.8. Most of the dummy variables of area type are significant. Since most affluent areas are omitted from the equation, their signs are all negative. In general, areas are ranked from affluent to poor. The size of regression equation coefficient reflects this ordering. Specific area type effect is the difference between the constant and AT(i). ERHH and PNR have the expected + and - effects on mean income projection. Growth in households seems to have a negative impact on Marin and San Francisco's mean incomes.

DHH, the difference in households (or occupied housing units) between two time periods is to capture the effect of household growth. In general, new residents are observed to have higher income potential than existing residents in growing areas. DHH is hypothesized to have a positive effect on mean income income. Jobs will bring in income; jobs in different industries and occupations will produce different income streams. Since the industry/occupation of employed residents is not included in the projection framework, only average employed residents per household (ERHH) is specified.

Many population and housing attributes of census tracts, which are related to income production, are not included in the ABAG projections. The area type classification from the social area study considered a large number of these attributes. The classification represents the best available characterization of the census tract areas. Hopefully, most of the effects of income-relevant attributes not specified would be captured by these area type dummy variables.

As carried out in Projections 83, the trend of projected mean household income was applied to the actual base year 1980 census tract mean income to calibrate the forecast year mean household income model. Aggregations, of these census tract projected mean household incomes, by ABAG's subregional study area were reviewed by Dr. Brady. Revised and rounded (to the nearest 100 dollars) mean household income by subregional study area was published in Projections 85.

Census tract mean income was then normalized to the corresponding sub-regional study area mean household incomes. Finally, normalized tract means were reviewed and hand adjusted if necessary. The statistics are available in the census tract files.

Mean income for MTC's 550 traffic zones was the aggregated tract mean weighted by the number of households. Zones are considered as a reporting unit. Zonal mean income was not subjected to extensive review.

Projection of Income Distribution

A gamma function is chosen for the income distribution by 17 income groups for years 2000 and 2005 at the census tract. (See pages 137-138, A. G. Wilson, "Urban and Regional Model" in Geography and Planning, John Wiley, 1974).

$$P(x) = \frac{\alpha^{n+1}}{\Gamma(n+1)} x^n e^{-\alpha x}$$

where

$$\alpha = \frac{\bar{x}}{\sigma^2}$$

$$n = \alpha \bar{x} - 1$$

Let

- $P(x)$ - the probability that a household has income x
- Γ - the gamma function
- x - the mean income
- σ^2 - the variance
- α, n - parameters

A value of n=5.38122 is found in ABAG's region. It is much larger comparing to Wilson's study (n=1.636 and 1.8).

$$\alpha = 21722/(8599)^2 = 0.0002938$$

$$n = \alpha \bar{x} - 1 = (21722)^2/(8599)^2 - 1 = 5.38122$$

In order to better understand the above distribution function, many plottings were made. Figure 2 plots ABAG regional income distribution with gamma function by three different n values. n = 5.38 curve approximates regional distribution in general.

County plottings were evaluated against social study areas. Each county was first plotted with 1980 census income distribution and followed by gamma function generated distribution. They are annotated as 'census' and 'gamma fn.' (Appendix C.)

The last three graphs plot census distribution vs. chosen gamma function distribution for three census tracts in Oakland. The gamma function does not simulate well in wealthy areas. This lack of fit is observed in the higher income ranges. Lower right corners of previous figure show this for all counties. (Figures 3-5.)

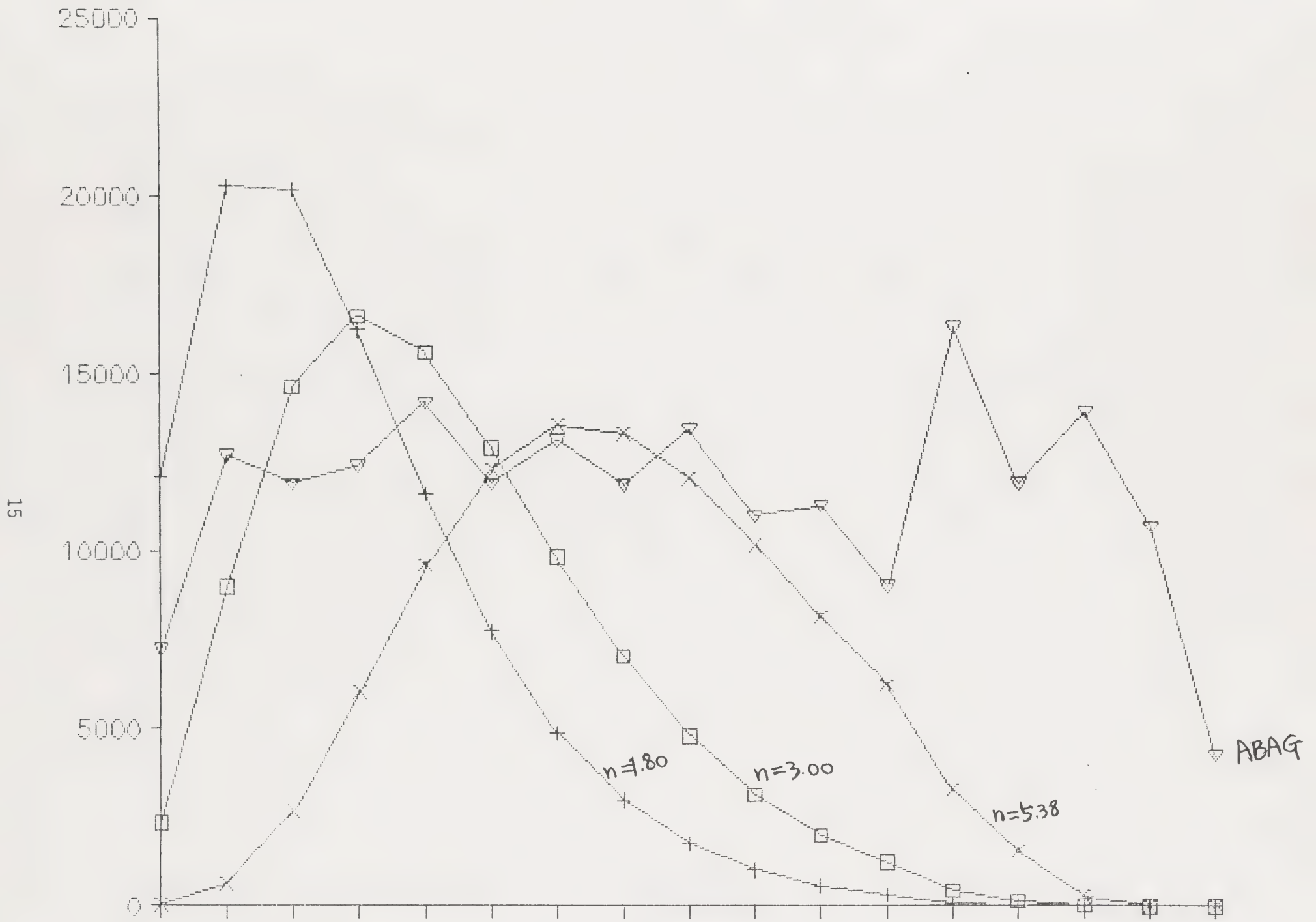
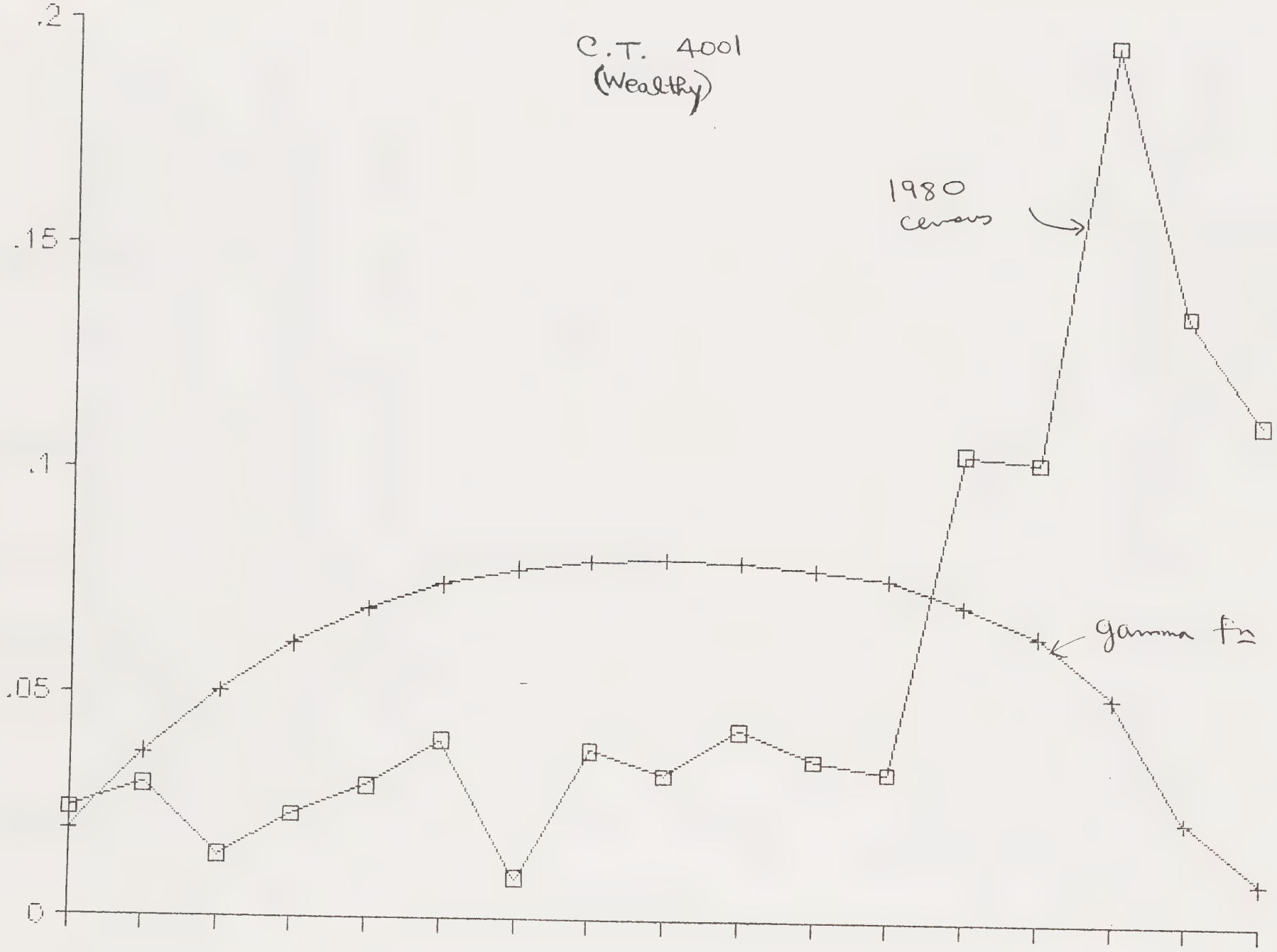
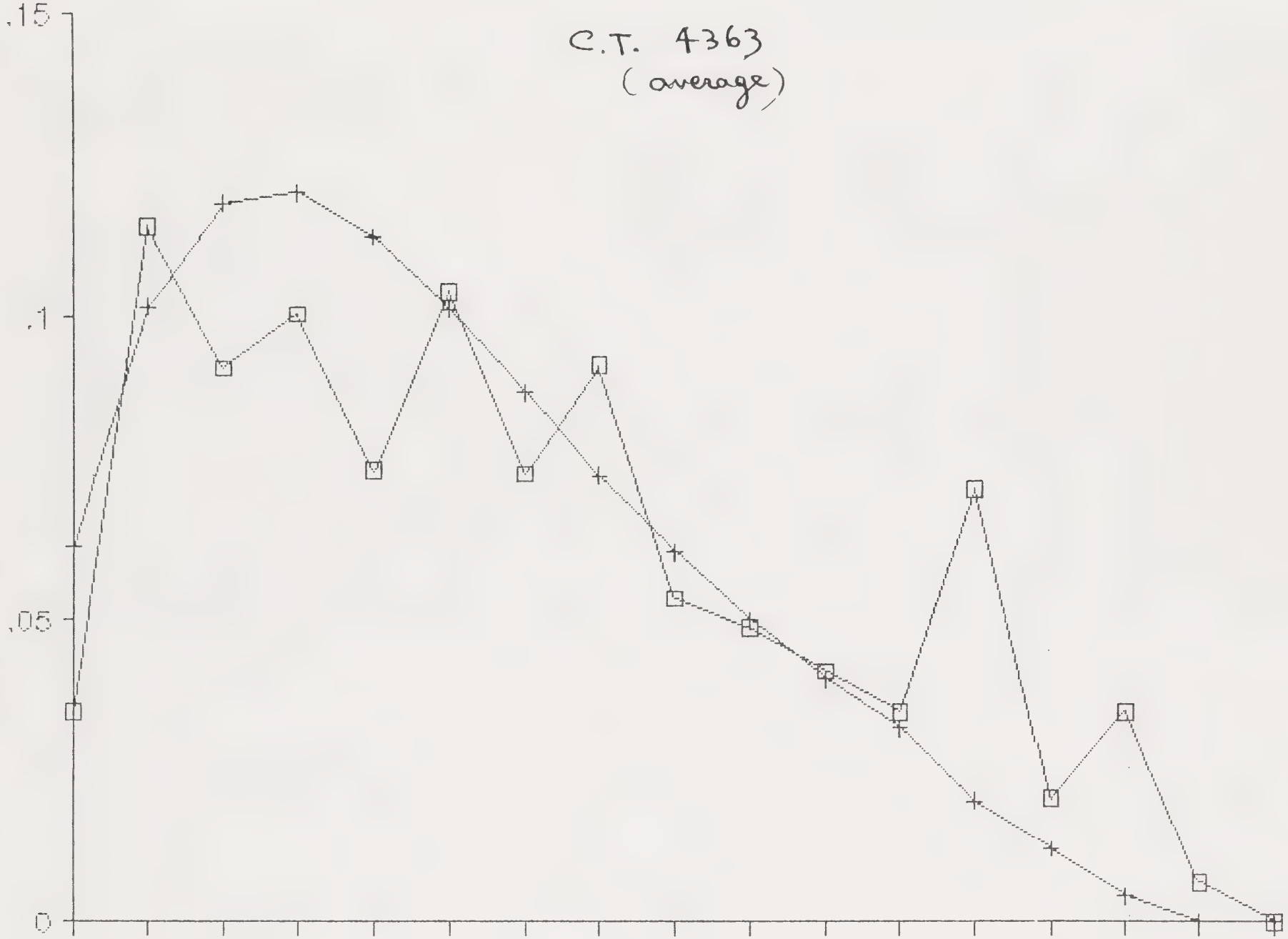


Figure 2 ABAG REGIONAL INCOME DISTRIBUTION
VS. GAMMA DISTRIBUTIONS



Figures 3-5 1980 CENSUS TRACT INCOME DISTRIBUTION
VS. CALIBRATED GAMMA DISTRIBUTION


C.T. 4363
(average)
.15
.1
.05
0
17

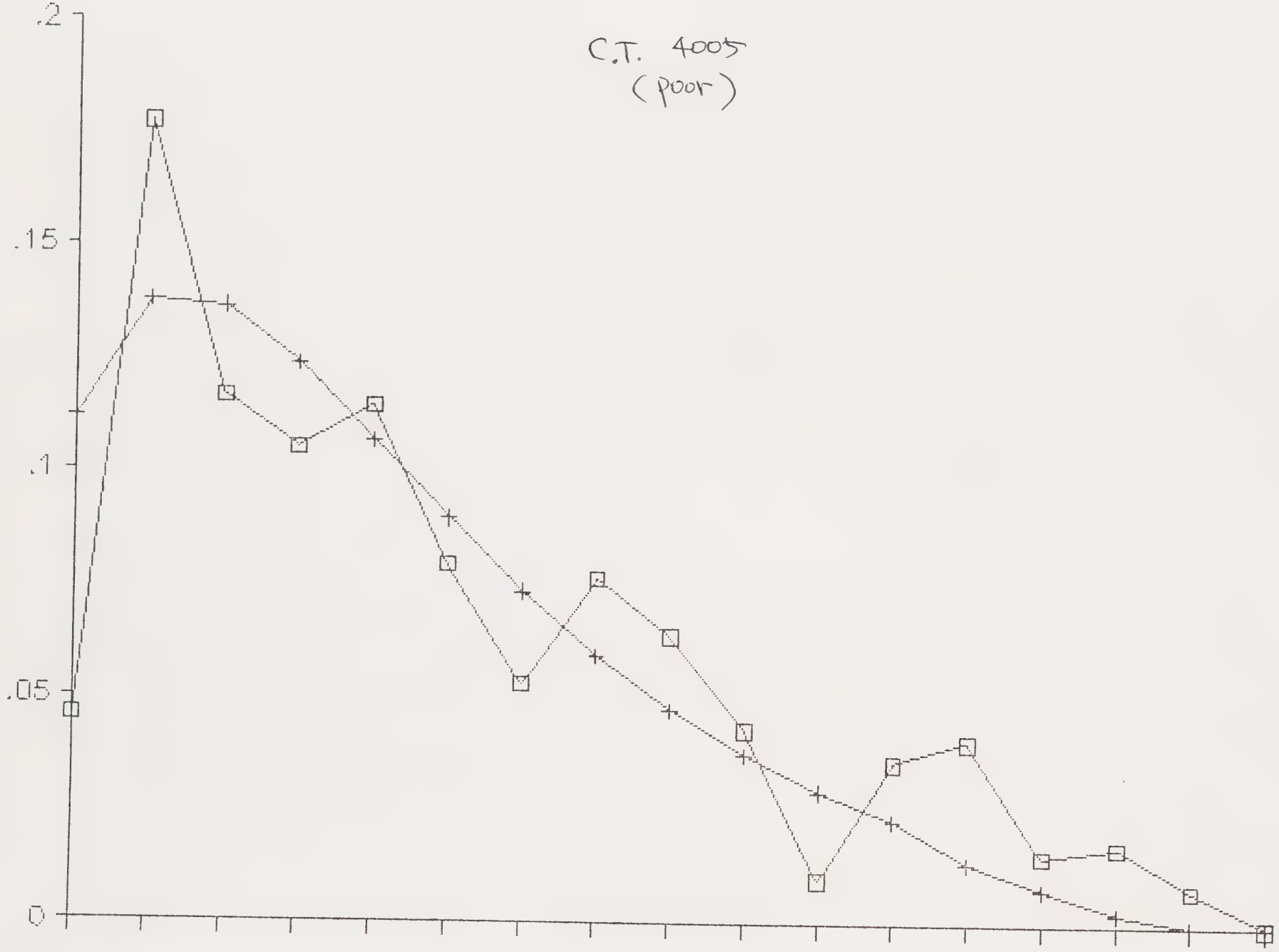

C.T. 4005
(poor)
.2
.15
.1
.05
0

Table 2 provides correlation between 1980 census and gamma function generated distribution for the region. Income ranges and assumed mid-point income for each group are also posted.

Income distribution was projected for 1980, 2000 and 2005 by using the gamma function. Forecast years' (2000 and 2005) distributions were then adjusted to reflect the 1980 base. That is, only the trend of the gamma function between the base year and the forecast year is used.

Finally, to cross check the validity of the distribution, mean income associated with the derived income distribution was computed for each census tract. This mean value was compared with the mean income obtained from the regression analyses. Large differences were found in tracts having relatively more households in the highest income group(group 17). Since group 17 has an open end range, its midpoint income was assumed to be 1.5 times of $75,000, or $112,500. This may not be the best assumption.

One plausible adjustment to the distribution was for tracts with no households in the 17th income group. Adjustments were made from higher to lower income groups. The adjustment process used an estimated aggregated income statistic and found appropriate number of households for assigning to lower income groups. This was carried out iteratively until aggregate income computed from the distribution and the projected mean income agreed.

Table 2 CORRELATION OF INCOME DISTRIBUTIONS BETWEEN 1980 CENSUS AND GAMMA FUNCTION

group	income in 1979 ($)	mid point ($)	r
1	0 - 2,500	1,667	.8699
2	2,500 - 4,999	4,166	.8764
3	5,000 - 7,499	6,250	.8883
4	7,500 - 9,999	8,750	.8846
5	10,000 - 12,499	11,250	.8501
6	12,500 - 14,999	13,750	.8173
7	15,000 - 17,499	16,250	.7989
8	17,500 - 19,999	18,750	.7884
9	20,000 - 22,499	21,250	.8213
10	22,500 - 24,999	23,750	.8225
11	25,000 - 27,499	26,250	.8342
12	27,500 - 29,999	28,750	.8151
13	30,000 - 34,999	32,500	.8573
14	35,000 - 39,999	37,500	.8505
15	40,000 - 49,999	45,000	.8352
16	50,000 - 74,999	62,500	.7742
17	75,000 +	112,500	.8942

LAND USE ACCOUNTING

A simple routine was developed to produce land use variables over the projection periods. The routine was implemented after all the variables in the census tract file were derived. The census tract allocation model which allocates all the variables from 114 superzones to 1209 census tracts has a land use submodel to project tract land use. As in other submodels, the land use submodel takes acres by land use of the superzones and distributes them to the census tracts in a given superzone. Since land use variables were not completely available from POLIS superzones, an independent land use accounting submodel was formulated.

Land acres by the following land uses are dealt with in the procedure:

(1) industrial developed land

(2) commercial developed land

(3) residential developed land

(4) commercial and industrial available land

(5) residential available land

(6) street and highway developed land

For a given census tract and in a given time period, density variables (employees per acre or housing units per acre) were used to transform activities (employment and household) to land acres. In all cases, available land statistics obtained from the local policy survey were the ceiling of the land development (i.e., change in developed land) over the projection period.

Industrial or basic land uses include agriculture, forestry and mining, manufacturing and wholesale trade activities. Commercial or local-serving land uses include retail trade, services, and other local-serving employment activities.

Initial computation of land use change was made disregarding the availability of land. If available, local policy survey density was used. This would be the case if both land and "unit" statistics were available in a given tract in a time period. If local policy survey density was unavailable, adjusted base year densities were used. Depending on the areal type (defined by the percent of developable land which were available), percents of adjustment were specified as follows:

$$\text{percent available} = \frac{\text{available land}}{(\text{total land} - \text{unavailable land})}$$

	<10%	10 - 75%	75%>
Industrial	20	10	10
Commercial	15	5	10
Residential	5	15	15

Initial estimation of the developed land change was compared to the available land. If enough land was available to accommodate the growth, available lands (gross acres) were subtracted (reduced) by the growth increment, and developed land uses (net acres) were updated accordingly. If available land was less than growth, the amount of available land became the developed land use increase. In essence, the activities were forced into the available land by assuming density increases. Then the available land was set to zero for the next period. There was no reallocation made for either intra- or inter-superzone.

Finally, street and highway land was estimated by applying the base year proportion of street and highway land to the derived land increments. Industrial, commercial, and residential (developed) lands were reduced by their share of the street and highway land.

In the future, if land use accounting at the superzone is working satisfactorily, intra-superzone reallocation of employment or occupied housing units due to land use availability constraints should be developed. Independent research on the land type and density shift by different areal types should be conducted to determine future land development densities.

PROJECTION OF PROPORTION OF SINGLE FAMILY BY 550 ZONES

One of the projection data requirements for MTC's travel demand forecast is the separation of single family dwelling units from non-single (or multiple family) units. Single family dwelling units are defined as the sum of 1-unit detached and 1-unit attached units according to the 1980 Census definition. This definition differs from previous ones because it includes 1-unit attached in addition to the 1-unit detached. Townhomes and rowhouses are examples of 1-unit attached housing units.

Previous efforts in projection of single family housing units were focused primarily on residential densities. It has been observed that housing structural types are closely related to residential densities. Since the new definition of single family included 1-unit attached, the calibration of the projection equation was expanded to include many other variables. In particular, attention was paid to ownership characteristics and zonal attributes.

Based on the 1980 zonal data base, the following regression equation was established to project the proportion of single family units:

$$P = 45.48 - 0.062\ RESDEN + 6.194\ ERHH - 31.28\ PCTNR + 0.895E - 3\ MEAN$$

$$(R^2 = 0.56,\quad F = 101.49)$$

Where P = Percent of households in single family, $0 \leq P \leq 100$

$RESDEN$ = residential density, i.e.,

$$\frac{\text{households}}{\text{residential acres}}$$

$ERHH$ = employed residents per household, i.e.,

$$\frac{\text{employed residents}}{\text{household}}$$

$PCTNR$ = proportion of non-residential land, i.e.

$$\frac{\text{industrial acres} + \text{commercial acres}}{\text{industrial acres} + \text{commercial acres} + \text{residential acres}}$$

$MEAN$ = mean household income

The projected percents were constrained to be non-negative and to be less than 100. Since the R^2 was only .56, the "trend" of the forecasted percent was used. That is, the 1980 base year percent of single family units is updated to all forecast years by multiplying the ratio of forecasted percents of year i + 5 over year i.

PROPOSED ADJUSTMENT PROCEDURE

Introduction

ABAG's Projections 85 provides 1980 census tract projections in five-year increments. The preliminary projection, before extensive review and revision by ABAG staff, did not satisfactorily reflect the pattern of development implied by ABAG's local development policy survey (LPS). This necessitated time-consuming staff review and adjustments of the projection statistics, particularly the land use forecasts. In addition, the census tract allocation was made on a "yearly" basis. That is, each five-year increment was projected independently from other projection years. For a given census tract, time trends over the 25 years projection were not examined or specified in the model. This section will present a procedure to improve the subareal allocation. An experiment with the procedure and the result will be discussed. A general purpose adjustment routine will be provided.

Adjustment Procedure

RAS, as applied in adopting the national input-output coefficients as regional coefficients, is the type of experimental procedure used to improve the projection result. This procedure attempts to mechanize the manual adjustment process. Discussions with staff members who reviewed and adjusted the data acknowledged that household adjustments were carried out in the following fashion:

(1) comparing growth increments of entire 25-year period (from year 1980 to 2005) with the total residential development potential units from the local policy survey (LPS) data base at the 1980 census tract;

(2) adjusting Projections 85 according to the LPS total potential units. This was carried out in backward chronological order, from year 2005 to 1985. The time trend was smoothed except where local policies constrained development. In most cases, residential unit changes were made by trading between census tracts in the same subregional area. County totals were generally observed in the adjustment.

(3) allowing 25-year increments to be different (in most cases greater) from the LPS in certain known subregional areas. These areas were understated in the LPS data and were permitted to grow beyond the extent expressed in the surveyed development potentials.

(4) adjusting population-related variables, e.g., household population, employed residents, and residential acres, based on the newly estimated residential units. Activity ratios derived prior to adjustments were used. They are household size, employed residents per household, and residential density (households per developed residential acre).

The proposed adjustment procedure is an iterative mechanical process which derives a rectangular matrix (1) to satisfy prespecified matrix row sums and column sums and (2) to be as similar as the distribution of the starting base matrix. This procedure can potentially be applied to employment allocation as well as population allocation.

As part of the ABAG projection series, there is available a detailed census tract projection which can be formulated as the starting base matrix. The projection usually incorporates recent information and revisions (as soon as they are available). In the top down process, there are forecasts produced by region, county, and subregional study areas. These statistics are formalized and available before the final census tract projection. They can be adapted as prespecified (or prescribed) column totals. Finally, total LPS derived housing units by census tract can be used as the row totals. For a given area to be subject to the procedure, grand totals have to be identical. That is, the sum of column totals has to be equal to the sum of row totals. In the total residential unit context, total expected growth units in a projection period should be identical either from the county projection or from LPS.

There are at least two points when the adjustment procedure can be applied at the census tract level. The first one is at the time of initial census tract allocation. This occurs immediately after the superzone allocation and before the subregional study area aggregation and review. The column totals can be either superzone totals or county totals. The second point is at the very final census tract review, i.e., before the review of census tract files by staff and after tract files are normalized normalized to the final Regional Planning Committee approved subregional study areas totals. As a matter of convenience, this experiment was conducted at the second point of time.

The following experiment used (A) Projections 83 and (B) Projections 85 increments by census tract as the starting base matrix. However, row totals (changes of household of 1980 to 2000) and column totals (yearly county changes of household) from Projections 85 were used as the targets for both experiments.

Experiment

Alameda County was selected for the experiment since it represented a typical area with a variety of development patterns. There are about 300 census tracts and four periods -- 1980 to 1985, 1985 to 1990, 1990 to 1995, and 1995 to 2000. Since year 2005 was not a projection year in Projections 83; it was not included in this experiment. Among the projection variables, the number of households is the instrumental one. Once the household units are determined, other population-related variables can be derived or cross checked. The experiment was made on the number of households.

The ABAG LPS provides potential residential acres and units by census tract for the entire projection period. This information is incorporated into Projections 85. The differences in residential units between the year 2000 and year 1980 are used as the target row totals. Similarly, the four column sums are the desired (target) totals of the selected area. In this experiment, Alameda County housing unit growth increments over the four time periods were the target column sums.

Result of Experiment

Overall results were as expected. The procedure worked well in terms of row and column total margins convergence. This occurred at about the fourth iteration. This means that control totals are readily met by the proposed procedure. An individual cell, the household increment in a census tract over a five-year period, depends very much on the magnitude of the starting base matrix. It simulates time trend of the base matrix (either Projections 83 or Projections 85) closely. If reliable estimates of total growth over time in census tract and total growth of a county over time are available, and if a satisfactory starting base matrix is available, the proposed procedure will be very useful to generate a new growth matrix for future projection tasks at ABAG.

One drawback of the procedure is that it cannot handle a matrix containing any negative cell. A negative cell means there is a decline in the activity. First of all, convergence is not guaranteed. In addition, if there is a decline in the entire projection period (a negative row sum) or if there is a one period decline (a negative cell) with overall increase (a positive row sum), normalized matrix cell values can be opposite to the intended direction of adjustment. In the second instance, negative cells will burden other non-negative cells of the same row in the procedure. This distorts the results greatly.

Since decline of activities in certain areas is a real phenomenon, negative numbers have to be dealt with. As implemented in the experiment, all cells with negative values are set to 0 and flagged for manual adjustments. This avoids the convergence problem and takes care of all non-negative tracts. Since the procedure is intended to supplement and improve the current projection approach, it probably will serve this purpose well.

A General Purpose Routine

An adjustment procedure subroutine is developed and is available for the next projection series. It is general and can be invoked to perform the adjustment whenever needed. Appendix D shows the annotated FORTRAN computer program. Figure 6 sketches the sequence of the procedure.

Two types of applications of the procedure are anticipated; they correspond with two dimensions of the matrix. The first type is applicable to different aggregations of geography: region, county, superzone, subregional study areas. The second type is applicable to different aggregations of time period data. It will be useful in utilizing ABAG's LPS data base. The demarcation of prior and post-1990 development potentials allows the procedure to be applied in two time periods, a useful application because short-term and long-term development potentials can be very different. If the procedure can treat the difference explicitly, the analyst will be better prepared for projection evaluation.

An example of the procedure is provided with fictitious data. As noted in the computer program, the routine handles increments only. This is largely because the LPS provides increments of activity information. Both starting and resulting matrix by increment and normal values matrix are provided in the example. "tb" and "td" are starting and target row sums, sums, "zb" and "zd" are starting and target column sums respectively. Since tract 4054 experiences a decline, it is signaled for special hand adjustment if needed.

Figure 6 FLOW CHART OF ADJUSTMENT PROCEDURE

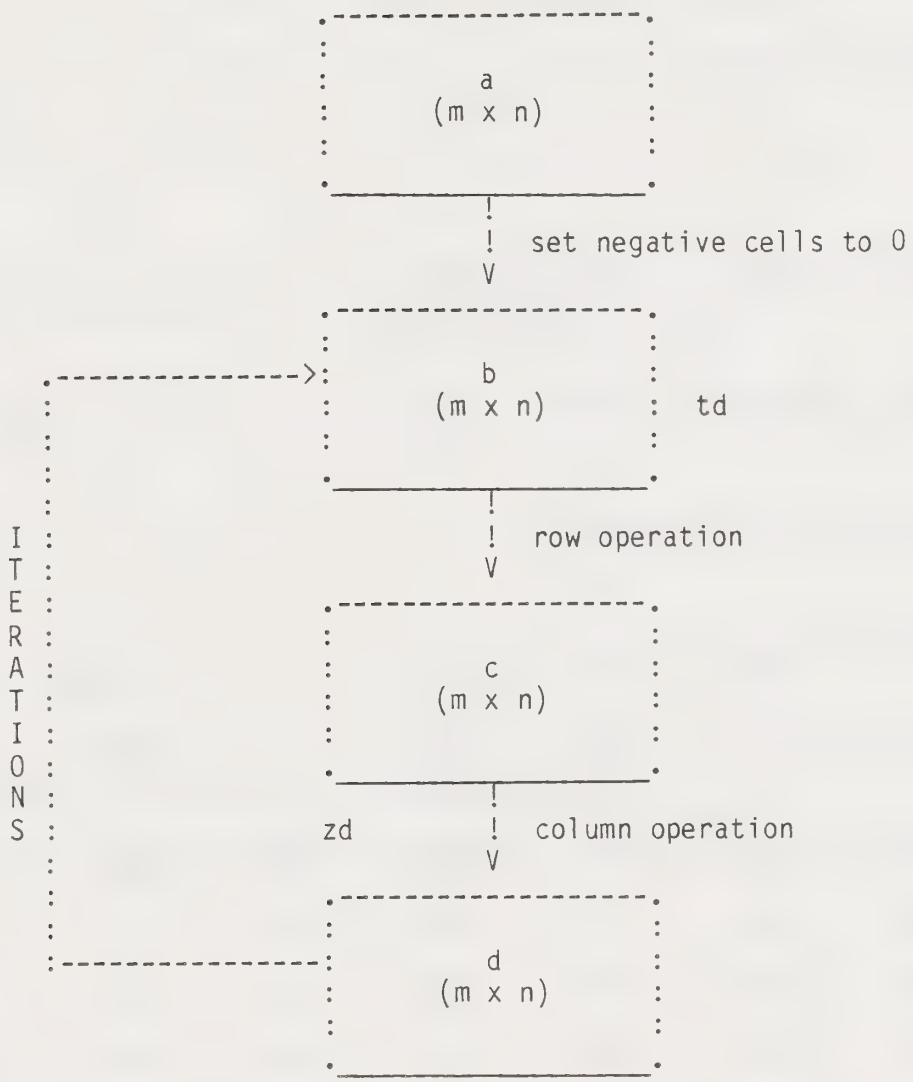


Table 3 **AN EXAMPLE OF PROPOSED ADJUSTMENT PROCEDURE**

STARTING INCREMENT MATRIX

Tract	80-85	85-90	90-95	95-00	00-05	tb	td
4001	60.	21.	55.	36.	7.	179.	200.
4002	17.	21.	58.	21.	13.	130.	100.
4054	-16.	52.	105.	67.	5.	213.	230.
4067	15.	39.	68.	27.	2.	151.	140.
zb	76.	133.	286.	151.	27.	693.	
zd	90.	100.	270.	160.	50.		670.

RESULTING INCREMENT MATRIX

Tract	80-85	85-90	90-95	95-00	00-05	td
4001	64.	18.	59.	43.	16.	200.
4002	12.	12.	41.	16.	19.	100.
4054*	0.	41.	105.	73.	11.	230.
4067	14.	29.	65.	28.	4.	140.
zd	90.	100.	270.	160.	50.	670.

STARTING MATRIX

Tract	1980	1985	1990	1995	2000	2005
4001	1060.	1120.	1141.	1196.	1232.	1239.
4002	912.	929.	950.	1008.	1029.	1042.
4054*	2634.	2618.	2670.	2775.	2842.	2847.
4067	2026.	2041.	2080.	2148.	2175.	2177.

RESULTING MATRIX

Tract	1980	1985	1990	1995	2000	2005
4001	1060.	1124.	1142.	1201.	1244.	1260.
4002	912.	924.	936.	976.	993.	1012.
4054*	2634.	2634.	2675.	2780.	2853.	2864.
4067	2026.	2040.	2069.	2134.	2162.	2166.

REFERENCES

Association of Bay Area Governments, The ABAG 1981-1982 Local Policy Survey Report, Forthcoming, Oakland, California, 1986.

Association of Bay Area Governments, Social Area Analysis of 9 San Francisco Bay Area Counties, 8 reports, Oakland, California, 1984.

Association of Bay Area Governments, PROJECTIONS '85, Oakland, California, 1985.

Association of Bay Area Governments, POLIS, The Land Use Information and Transportation System for the San Francisco Bay Area, Oakland, California, 1985.

Brady, R.J. and C.M. Yang, A Regional Information System for Economic, Demographic and Energy Analysis, Association of Bay Area Governments, Berkeley, California, 1982.

Brady, R.J. and C.M. Yang, "The Design and Implementation of a Regional Economic-Demographic Simulation Model," Annals of Regional Science, November 1983, pp. 1-22.

Brady, R.J. and C.M. Yang, A 1980 Hybrid Input-Output Model for The San Francisco Bay Region, Oakland, California, 1984.

Prastacos, P. and R.J. Brady, A County Employment Forecasting System (CEFS) for the San Francisco Bay Region, Oakland, California, 1984.

Wilson, A.G., Urban and Regional Models in Geography and Planning, John Wiley, London, 1974.

APPENDIX A

File Layout of Subarea Allocation Model

Census Tract File

Fields	Size	Description
1 - 2	I2	County Number (Alameda = 1, . . . Sonoma = 9)
3 - 5	I3	107 Superzone Number
6 - 8	I3	550 MTC Zone Number
9 - 14	I6	1980 Census Tract Number
15 - 20	F6.0	Employment in Agriculture, Forestry, & Mining
21 - 26	F6.0	Employment in Manufacturing
27 - 32	F6.0	Employment in Wholesale Trade
33 - 38	F6.0	Employment in Retail Trade
39 - 44	F6.0	Employment in Services
45 - 50	F6.0	Employment in Others
51 - 56	F6.0	Industrial Land Acres
57 - 62	F6.0	Commercial Land Acres
63 - 68	F6.0	Street and Highway Acres
69 - 74	F6.0	Residential Available Acres
75 - 79	F5.0	Industrial and Commercial Acres
80 - 86	F7.0	Vacant Unavailable Acres
87 - 93	F7.0	Household Number
94 - 100	F7.0	Household Population
101 - 107	F7.0	Group Quarters Population
108 - 114	F7.0	Employed Resident
115 - 121	F7.4	Fraction Single Families
122 - 128	F7.0	Mean Household Income
129 - 135	F7.0	Median Household Income
136 - 142	F7.0	Number of Household in 1979 Income $ 0 - 12,499

Census Tract File

Fields	Size	Description
143 - 149	F7.0	Number of Household in 1979 Income $12,500 - 29,999
150 - 156	F7.0	Number of Household in 1979 Income $30,000 or more
157 - 163	F7.0	Total Acres
164 - 170	F7.0	Residential Acres
171 - 177	F7.1	Development Potentials, Residential Acres
178 - 184	F7.1	Development Potentials, Residential Unit
185 - 191	F7.1	Development Potentials, Basic Acre
192 - 198	F7.1	Development Potentials, Basic Employment
199 - 205	F7.1	Development Potentials, Non-basic Acre
206 - 212	F7.1	Development Potentials, Non-basic Employment

Superzone File

Fields	Size	Description
1 - 4	I4	Superzone Number
5 - 11	F7.0	Employment in Agriculture, Forestry & Mining
12 - 18	F7.0	Employment in Manufacturing
19 - 25	F7.0	Employment in Wholesale Trade
26 - 32	F7.0	Employment in Retail Trade
33 - 39	F7.0	Employment in Services
40 - 46	F7.0	Employment in Others
47 - 53	F7.0	Industrial Land Acres
54 - 60	F7.0	Commercial Land Acres
61 - 67	F7.0	Street and Highway Acres
68 - 74	F7.0	Residential Available Acres
75 - 81	F7.0	Industrial and Commercial Acres
82 - 88	F7.0	Vacant Unavailable Acres
89 - 85	F7.0	Total Population
96 - 102	F7.0	Household Population
103 - 109	F7.0	Employed Resident
110 - 116	F7.0	Household Number
117 - 123	F7.0	Total Acres
124 - 130	F7.0	Residential Acres

1980 Land Use File

Fields	Size	Description
1 - 7	I4	1980 Census Tract Number
8 - 15	i8	Total Acres
16 - 20	I5	Residential Acres
21 - 25	I5	Local Serving Acres
26 - 30	I5	Basic Acres
31 - 35	I5	Street and Highway Acres
36 - 40	I5	Rebuilding/Conversion Acres
41 - 45	I5	Vacant Available Acres
46 - 51	I6	Vacant Unavailable Acres

Partitioned Census Tract File

Fields	Size	Description
1 - 4	I4	Subregional Study Area Number
5 - 8	I4	Census Tract Seq. # (sorted by Superzone & C.T. #)
9 - 14	I6	1980 Cenus Tract Number
15 - 34	A20	Name of the Subregional Study Area
35 - 42	F8.0	Total Population
43 - 50	F8.0	Household Number
51 - 58	F8.0	Household Population
59 - 66	F8.0	Employment in Agriculture, Forestry & Mining
67 - 74	F8.0	Employment in Manufacturing
75 - 82	F8.0	Employment in Wholesale Trade
83 - 90	F8.0	Employment in Retail Trade
91 - 98	F8.0	Employment in Services
99 - 106	F8.0	Employment in Others

APPENDIX B

Correspondence Table of Superzone and Census Tract

COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT	COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT	COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT
5	1	411	13300	5	5	415	15500	5	10	367	61000
5	1	411	15400	5	5	412	15600	5	11	379	25100
5	1	410	40100	5	5	412	15700	5	11	379	25200
5	1	409	40200	5	5	413	15800	5	11	379	25300
5	1	406	42600	5	5	414	15900	5	11	543	25400
5	1	406	42700	5	5	414	16000	5	12	544	25500
5	1	406	42800	5	5	414	16100	5	12	372	25600
5	1	410	45100	5	5	396	16200	5	12	372	25700
5	1	409	45200	5	5	396	16300	5	12	372	25800
5	1	407	47600	5	5	396	16400	5	12	372	25900
5	1	407	47700	5	5	412	16500	5	12	373	26000
5	1	405	47800	5	6	397	16600	5	12	545	26100
5	1	405	47900	5	6	395	16700	5	12	545	26200
5	1	408	60100	5	6	395	16800	5	12	374	26300
5	1	405	60200	5	6	395	16900	5	12	542	26400
5	1	404	60300	5	6	397	17000	5	12	542	60500
5	2	440	12600	5	6	397	17100	5	13	392	30700
5	2	439	12700	5	7	388	20300	5	13	546	30900
5	2	439	12800	5	7	388	20500	5	13	375	31000
5	2	440	12900	5	7	388	20600	5	13	375	31100
5	2	549	13000	5	7	389	21100	5	13	376	31200
5	2	549	13100	5	7	389	21200	5	13	546	31300
5	2	438	13200	5	7	389	21300	5	13	376	31400
5	2	438	13400	5	7	389	21400	5	13	377	33200
5	2	438	13500	5	7	390	21500	5	13	378	60400
5	3	432	10100	5	7	390	21600	5	14	394	20400
5	3	436	10200	5	7	391	21700	5	14	393	30101
5	3	435	10300	5	7	391	21800	5	14	393	30102
5	3	433	10400	5	8	384	17700	5	14	398	30200
5	3	431	10500	5	8	386	20100	5	14	398	30300
5	3	431	10599	5	8	386	20200	5	14	399	30400
5	3	434	10600	5	8	387	20700	5	14	394	30500
5	3	434	10700	5	8	387	20800	5	14	399	30600
5	3	435	10800	5	8	387	20900	5	14	399	30800
5	3	437	10900	5	8	387	21000	5	15	401	32600
5	3	437	11000	5	8	385	22800	5	15	401	32700
5	3	417	11100	5	8	385	22900	5	15	400	32800
5	3	419	11200	5	9	548	17800	5	15	400	32900
5	3	420	11300	5	9	382	17901	5	15	547	33000
5	3	420	11400	5	9	550	17902	5	15	547	33100
5	3	430	11500	5	9	550	17999	5	15	403	35100
5	3	429	11600	5	9	383	18000	5	15	403	35200
5	3	420	11800	5	9	380	22600	5	15	402	35300
5	3	419	11900	5	9	380	22699	5	15	402	35400
5	3	419	12100	5	9	380	22700	6	16	366	600100
5	4	421	11700	5	9	381	60700	6	16	366	600200
5	4	418	12000	5	10	371	23000	6	16	366	600300
5	4	418	12200	5	10	369	23100	6	16	541	600400
5	4	423	12300	5	10	369	23200	6	16	541	600500
5	4	424	12400	5	10	371	23300	6	16	365	600600
5	4	423	12500	5	10	367	23400	6	16	365	600700
5	4	425	17601	5	10	368	60600	6	16	363	600800
5	4	427	17602	5	10	368	60699	6	16	363	600900
5	5	416	15100	5	10	369	60800	6	16	540	601000
5	5	416	15200	5	10	369	60899	6	16	540	601100
5	5	415	15300	5	10	370	60900	6	16	363	601200

COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT	COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT	COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT
6	16	364	601300	6	21	337	606300	6	24	315	611400
6	16	362	601400	6	21	336	606400	6	25	312	611500
6	16	362	601500	6	21	336	606500	6	25	312	611600
6	16	364	601601	6	21	336	606600	6	25	307	611700
6	16	361	601602	6	21	335	606700	6	25	306	611800
6	16	361	601603	6	21	333	606800	6	25	308	611900
6	17	359	601700	6	21	333	606900	6	25	308	612000
6	17	359	601800	6	21	333	607000	6	25	309	612100
6	17	359	601900	6	21	327	607100	6	25	309	612200
6	17	358	602000	6	21	327	607200	6	25	309	612300
6	17	358	602100	6	21	327	607300	6	25	309	612400
6	17	358	602200	6	21	335	607400	6	25	311	612500
6	17	357	602300	6	21	339	607500	6	25	310	612600
6	17	349	602400	6	21	338	607600	6	25	310	612700
6	17	360	602500	6	21	340	607700	6	25	310	612800
6	17	360	602600	6	21	340	607800	6	25	316	612900
6	18	348	603500	6	21	339	608500	6	25	316	613000
6	18	348	603600	6	22	326	608600	6	26	305	613100
6	18	348	603700	6	22	326	608700	6	26	305	613200
6	18	351	603800	6	22	334	608800	6	26	317	613300
6	18	352	603900	6	22	334	608900	6	26	317	613400
6	18	352	604000	6	22	326	609000	6	26	328	613800
6	18	353	604101	6	22	314	609100	7	27	299	510600
6	18	350	604102	6	22	324	609200	7	27	299	510700
6	18	353	604200	6	22	324	609400	7	27	287	510801
6	19	347	602700	6	22	324	609500	7	27	287	510802
6	19	347	602800	6	22	318	609601	7	27	287	510803
6	19	347	602900	6	22	318	609602	7	27	299	510900
6	19	539	603000	6	22	318	609603	7	27	300	511000
6	19	539	603100	6	22	318	609700	7	27	300	511100
6	19	346	603200	6	23	341	607900	7	27	302	511200
6	19	346	603300	6	23	341	608001	7	27	302	511300
6	19	346	603400	6	23	341	608002	7	27	303	511400
6	19	330	613500	6	23	341	608003	7	27	303	511500
6	19	325	613600	6	23	341	608004	7	27	304	511601
6	19	329	613700	6	23	342	608100	7	27	304	511602
6	20	356	604300	6	23	342	608200	7	27	304	511603
6	20	354	604400	6	23	342	608300	7	28	285	509801
6	20	345	604500	6	23	341	608400	7	28	285	509802
6	20	345	604600	6	24	321	609300	7	28	284	509901
6	20	345	604700	6	24	319	609800	7	28	284	509902
6	20	345	604800	6	24	321	609900	7	28	284	510001
6	20	344	604900	6	24	321	610000	7	28	284	510002
6	20	344	605000	6	24	322	610100	7	28	284	510100
6	20	355	605100	6	24	322	610200	7	28	285	510200
6	20	344	605200	6	24	323	610300	7	28	286	510300
6	20	343	605300	6	24	313	610400	7	28	286	510400
6	20	343	605400	6	24	313	610500	7	28	286	510500
6	20	343	605500	6	24	313	610600	7	28	241	511701
6	20	331	605600	6	24	320	610700	7	28	241	511702
6	20	332	605700	6	24	320	610800	7	28	241	511703
6	20	343	605800	6	24	320	610900	7	28	241	511704
6	21	337	605900	6	24	320	611000	7	29	298	504601
6	21	337	606000	6	24	319	611100	7	29	298	504700
6	21	340	606100	6	24	319	611200	7	29	282	509104
6	21	337	606200	6	24	315	611300	7	29	282	509105

COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT	COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT	COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT
7	29	289	509201	7	33	274	505600	7	37	516	503002
7	29	289	509202	7	33	274	505700	7	37	516	503003
7	29	288	509301	7	33	275	505800	7	38	255	501700
7	29	288	509302	7	33	275	505900	7	38	255	501800
7	29	288	509401	7	33	275	506000	7	38	251	502101
7	29	288	509402	7	33	276	506101	7	38	251	502102
7	29	289	509500	7	33	276	506102	7	38	253	502200
7	29	289	509600	7	33	276	506103	7	38	253	502300
7	29	289	509700	7	34	246	506202	7	38	255	502400
7	30	242	507701	7	34	246	506203	7	38	232	502500
7	30	242	507702	7	34	246	506204	7	38	234	502901
7	30	242	507703	7	34	263	506301	7	38	234	502902
7	30	243	507801	7	34	263	506302	7	38	234	502903
7	30	243	507803	7	34	250	506304	7	38	232	503001
7	30	243	507804	7	34	250	506305	7	39	259	500100
7	30	535	508001	7	34	263	506401	7	39	260	500200
7	30	535	508002	7	34	263	506402	7	39	261	500300
7	30	244	508101	7	34	245	507901	7	39	262	500400
7	30	244	508102	7	34	245	507903	7	39	264	500500
7	31	279	508201	7	34	245	507904	7	39	262	500600
7	31	279	508202	7	35	252	502601	7	39	254	500700
7	31	534	508301	7	35	252	502602	7	39	265	500800
7	31	534	508303	7	35	249	506501	7	39	256	500900
7	31	534	508304	7	35	249	506502	7	39	256	501000
7	31	283	508401	7	35	249	506503	7	39	259	501100
7	31	283	508402	7	35	248	506601	7	39	256	501200
7	31	533	508503	7	35	536	506603	7	39	256	501300
7	31	533	508504	7	35	536	506604	7	39	258	501400
7	31	532	508505	7	35	248	506605	7	39	258	501500
7	31	532	508506	7	35	248	506606	7	39	256	501600
7	32	290	504802	7	35	537	506701	7	39	254	501900
7	32	290	504803	7	35	537	506702	7	39	264	502000
7	32	290	504804	7	35	537	506703	7	40	297	504407
7	32	281	508600	7	36	236	506801	7	40	297	504501
7	32	280	508701	7	36	236	506802	7	40	296	504503
7	32	531	508702	7	36	538	506803	7	40	529	504602
7	32	531	508703	7	36	236	506804	7	41	295	504402
7	32	280	508800	7	36	538	506900	7	41	297	504406
7	32	531	508900	7	36	237	507000	7	41	295	504408
7	32	280	509000	7	36	238	507100	7	41	294	504409
7	32	530	509102	7	36	238	507202	7	41	294	504410
7	32	281	509103	7	36	238	507203	7	41	294	504411
7	33	291	504901	7	36	238	507204	7	42	528	504902
7	33	291	505001	7	36	239	507301	7	42	528	505002
7	33	273	505201	7	36	239	507302	7	42	271	505100
7	33	277	505202	7	36	247	507401	7	43	292	504303
7	33	274	505203	7	36	247	507402	7	43	292	504304
7	33	278	505301	7	36	240	507500	7	43	293	504305
7	33	278	505302	7	36	240	507600	7	43	293	504306
7	33	277	505303	7	37	235	502701	7	43	293	504307
7	33	278	505304	7	37	235	502702	7	43	293	504308
7	33	278	505305	7	37	235	502800	7	44	257	503400
7	33	272	505401	7	37	515	502905	7	44	266	503504
7	33	272	505402	7	37	515	502906	7	44	266	503505
7	33	272	505403	7	37	233	502907	7	44	270	503601
7	33	277	505500	7	37	233	502908	7	44	526	503602

COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT	COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT	COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT
7	44	526	503702	7	52	222	512501	1	56	141	401700
7	44	526	503703	7	52	222	512502	1	56	141	401799
7	44	270	503704	7	52	218	512600	1	56	140	401800
7	44	270	503705	1	53	125	420100	1	56	141	401900
7	45	527	503502	1	53	125	420200	1	56	141	401999
7	45	527	503503	1	53	126	420300	1	56	141	402000
7	45	269	503801	1	53	126	420400	1	56	140	402100
7	45	269	503802	1	53	125	420500	1	56	140	402200
7	45	269	503900	1	53	125	420600	1	56	140	402300
7	45	267	504000	1	53	125	421300	1	56	140	402400
7	45	267	504100	1	53	128	421800	1	56	140	402500
7	45	268	504200	1	53	128	421900	1	56	143	402600
7	46	228	503304	1	53	127	422000	1	56	144	402700
7	46	228	503305	1	53	127	422100	1	56	144	402800
7	46	228	503306	1	53	128	422200	1	56	144	402900
7	46	524	503307	1	53	128	422300	1	56	143	403000
7	46	524	503308	1	53	134	423000	1	56	143	403100
7	46	227	503309	1	53	134	423100	1	56	142	403200
7	46	227	503310	1	53	127	423200	1	56	142	403299
7	47	231	503101	1	53	134	423300	1	56	142	403300
7	47	525	503102	1	53	134	423400	1	56	144	403400
7	47	231	503103	1	53	134	424000	1	56	145	403500
7	47	230	503104	1	54	132	400100	1	56	145	403600
7	47	229	503203	1	54	124	421100	1	56	145	403700
7	47	229	503204	1	54	124	421200	1	57	495	427200
7	47	523	503205	1	54	124	421400	1	57	495	427299
7	47	522	503206	1	54	123	421500	1	57	164	427300
7	47	523	503207	1	54	123	421600	1	57	164	427399
7	47	522	503208	1	54	129	421700	1	57	162	427400
7	48	521	512002	1	54	129	422400	1	57	162	427499
7	48	517	512005	1	54	130	422500	1	57	162	427500
7	48	517	512006	1	54	130	422600	1	57	162	427599
7	48	225	512007	1	54	131	422700	1	57	163	427600
7	48	518	512008	1	54	131	422800	1	57	163	427700
7	49	520	512009	1	54	129	422900	1	58	166	427100
7	49	520	512010	1	54	133	423500	1	58	164	427800
7	49	226	512011	1	54	133	423600	1	58	164	427900
7	49	226	512012	1	54	132	423700	1	58	495	428000
7	49	226	512013	1	54	132	423800	1	58	166	428100
7	49	519	512014	1	54	133	423900	1	58	167	428200
7	49	519	512015	1	55	137	400200	1	58	165	428400
7	49	519	512016	1	55	137	400300	1	58	165	428500
7	50	223	511800	1	55	137	400400	1	58	165	428600
7	50	514	511901	1	55	137	400500	1	59	168	428300
7	50	514	511903	1	55	137	400600	1	60	146	405200
7	50	514	511904	1	55	136	400700	1	60	492	405300
7	50	513	511905	1	55	136	400800	1	60	492	405400
7	50	513	511906	1	55	136	400900	1	60	146	405500
7	50	224	511907	1	55	138	401000	1	60	146	405600
7	50	224	511908	1	55	138	401100	1	60	493	405700
7	51	221	512100	1	55	138	401200	1	60	493	405800
7	51	220	512301	1	55	135	425100	1	60	160	405900
7	51	217	512302	1	56	139	401300	1	60	161	406000
7	51	219	512400	1	56	139	401400	1	60	160	406200
7	51	217	512700	1	56	139	401500	1	60	493	406300
7	52	223	512200	1	56	139	401600	1	60	493	406400

COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT	COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT	COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT
1	61	147	403800	1	65	498	410400	1	70	189	436600
1	61	491	403900	1	66	174	432100	1	70	502	436700
1	61	491	404000	1	66	174	432200	1	70	189	436800
1	61	491	404100	1	66	175	432300	1	70	502	436900
1	61	158	404700	1	66	170	432400	1	70	190	437000
1	61	158	404800	1	66	499	432500	1	70	190	437100
1	61	147	404900	1	66	175	432600	1	70	190	437200
1	61	147	405000	1	66	174	432700	1	70	190	437300
1	61	147	405100	1	66	180	432800	1	70	192	438200
1	61	494	406600	1	66	180	432900	1	70	192	438300
1	61	158	406700	1	66	180	433000	1	70	192	438400
1	61	158	406800	1	66	176	433100	1	71	504	440100
1	61	157	406900	1	66	176	433200	1	71	504	440200
1	61	494	407000	1	66	177	433300	1	71	194	440307
1	61	157	407800	1	66	170	433400	1	71	504	440308
1	61	157	407900	1	66	177	433500	1	71	504	440309
1	62	149	404200	1	66	177	433600	1	72	194	440301
1	62	149	404300	1	67	178	433700	1	72	503	440302
1	62	150	404400	1	67	179	433800	1	72	503	440303
1	62	150	404500	1	67	179	433900	1	72	503	440304
1	62	151	404600	1	67	179	434000	1	72	503	440305
1	62	152	408000	1	67	178	435600	1	72	503	440306
1	62	152	408100	1	67	178	435700	1	73	200	441500
1	62	148	426100	1	67	501	435800	1	74	201	444100
1	62	148	426200	1	67	500	435900	1	74	201	444200
1	63	496	406100	1	67	500	436000	1	74	506	444300
1	63	159	406500	1	67	501	436100	1	74	201	444400
1	63	159	407100	1	68	186	430100	1	74	202	444500
1	63	159	407200	1	68	183	430200	1	74	202	444600
1	63	156	407400	1	68	182	430300	1	75	195	441600
1	63	156	407500	1	68	182	430400	1	75	196	441700
1	63	156	407600	1	68	181	430500	1	75	197	441800
1	63	156	407700	1	68	181	430600	1	75	204	441901
1	63	155	408200	1	68	182	430700	1	75	204	441902
1	63	155	408600	1	68	183	430800	1	75	507	442500
1	63	155	408700	1	68	184	430900	1	75	196	442600
1	63	172	408800	1	68	184	431000	1	75	196	442700
1	63	172	408900	1	68	184	431100	1	75	507	442800
1	64	172	407300	1	68	184	431200	1	75	508	442900
1	64	169	409000	1	69	187	435100	1	76	198	441100
1	64	171	409100	1	69	188	435200	1	76	198	441200
1	64	171	409200	1	69	188	435300	1	76	195	441300
1	65	154	408300	1	69	188	436400	1	76	505	441400
1	65	497	408400	1	69	187	436500	1	76	509	442000
1	65	497	408500	1	69	191	437400	1	76	509	442100
1	65	173	409300	1	69	191	437500	1	76	509	442200
1	65	173	409400	1	69	191	437600	1	76	203	442300
1	65	173	409500	1	69	191	437700	1	76	508	442400
1	65	497	409600	1	69	191	437800	1	76	203	443000
1	65	497	409700	1	69	187	437900	1	76	199	443100
1	65	154	409800	1	69	193	438000	1	76	200	443200
1	65	153	409900	1	69	193	438100	1	76	200	443300
1	65	153	410000	1	70	185	435400	1	77	207	450100
1	65	498	410100	1	70	185	435500	1	77	206	450200
1	65	498	410200	1	70	502	436200	1	77	206	450300
1	65	498	410300	1	70	189	436300	1	77	205	450400

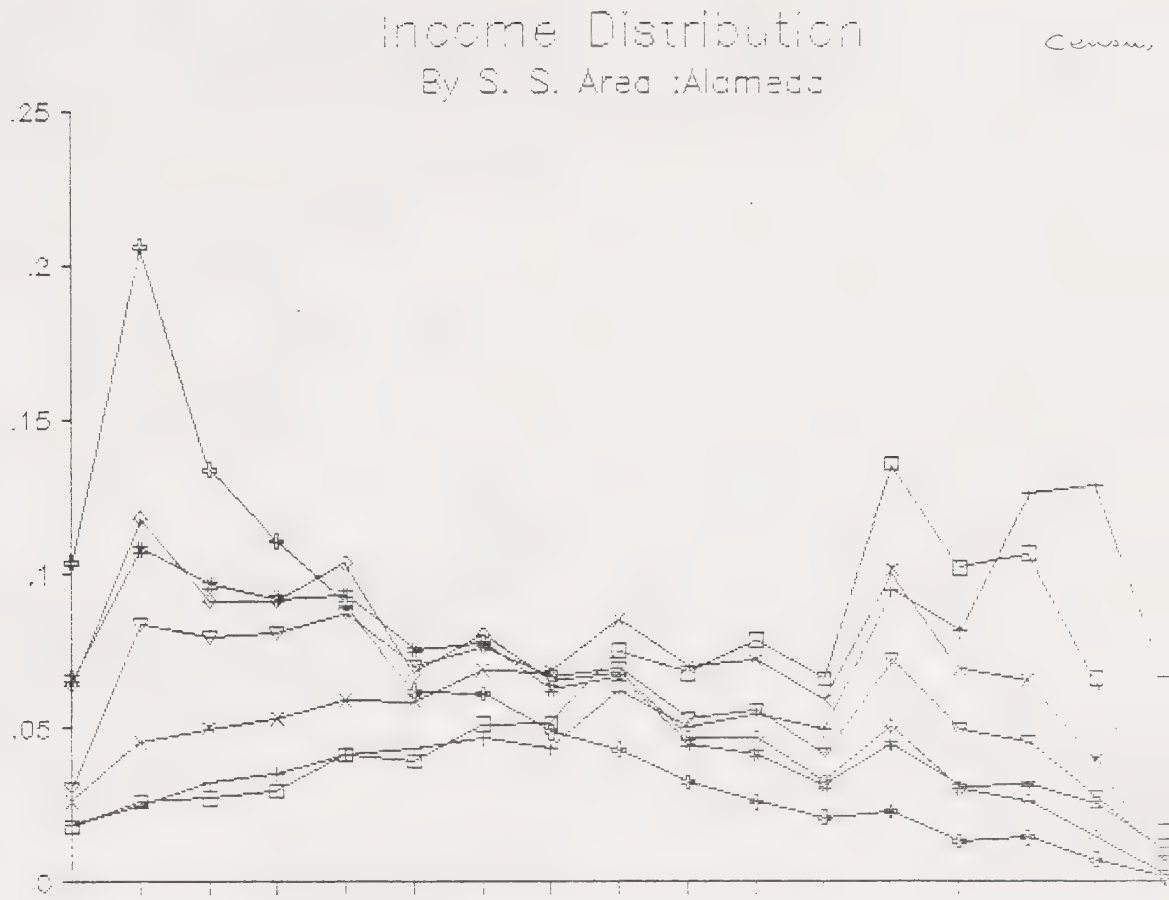
COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT	COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT	COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT
1	77	205	450500	2	82	122	391000	2	87	485	351100
1	78	209	450601	2	82	122	392000	2	87	101	355302
1	78	209	450602	2	83	488	356001	2	88	483	320002
1	78	510	450603	2	83	107	356002	2	88	483	321101
1	78	208	450604	2	83	488	357000	2	88	484	321102
1	78	208	450605	2	83	488	358000	2	88	484	321103
1	78	208	450606	2	83	488	358099	2	88	106	321200
1	78	211	450607	2	83	489	359101	2	88	106	322000
1	78	211	450701	2	83	489	359102	2	88	105	323000
1	78	210	450702	2	83	110	359201	2	88	105	324000
1	78	208	450703	2	83	110	359202	2	88	97	325000
1	78	211	450704	2	83	107	360100	2	88	97	326000
1	79	216	451100	2	83	111	364001	2	88	96	340001
1	79	215	451200	2	83	111	364002	2	88	96	340002
1	79	511	451300	2	84	108	315000	2	88	97	347000
1	79	213	451400	2	84	108	315099	2	89	95	348000
1	79	214	451500	2	84	109	316000	2	89	93	349000
1	79	212	451600	2	84	109	317000	2	89	90	350000
1	79	512	451700	2	84	109	318000	2	89	93	351200
2	80	490	365001	2	84	109	319000	2	89	89	352101
2	80	112	365002	2	84	108	320001	2	89	89	352102
2	80	490	366000	2	84	108	320099	2	89	89	352201
2	80	490	367100	2	85	104	327000	2	89	89	352202
2	80	113	367200	2	85	480	328000	2	89	91	353001
2	80	112	368000	2	85	479	329000	2	89	91	353002
2	80	113	369000	2	85	479	330000	2	89	92	354000
2	81	114	360200	2	85	480	336100	2	90	86	344000
2	81	114	361000	2	85	480	336200	2	90	487	345101
2	81	119	362000	2	85	481	337200	2	90	487	345102
2	81	114	363000	2	85	481	338100	2	90	487	345103
2	81	119	370000	2	86	103	331000	2	90	85	345104
2	81	115	371000	2	86	103	332000	2	90	486	345201
2	81	115	372000	2	86	477	333100	2	90	88	346101
2	81	118	373000	2	86	477	333200	2	90	88	346102
2	81	115	374000	2	86	102	334001	2	90	87	346201
2	81	118	375000	2	86	478	334002	2	90	87	346202
2	81	118	376000	2	86	478	334003	2	90	87	355103
2	81	118	377000	2	86	102	335000	2	91	84	345105
2	81	117	378000	2	86	102	337100	2	91	84	345106
2	81	117	378099	2	86	83	355102	2	91	85	345202
2	81	117	379000	2	86	477	355200	2	92	74	309000
2	81	117	380000	2	86	83	355301	2	92	74	310000
2	81	117	380099	2	86	83	355303	2	92	74	311000
2	81	116	381000	2	86	83	355304	2	92	74	312000
2	81	116	382000	2	86	83	355305	2	92	476	313101
2	82	121	383000	2	87	101	337300	2	92	476	313102
2	82	120	384000	2	87	100	338201	2	92	476	313103
2	82	122	385100	2	87	100	338202	2	92	75	313201
2	82	120	385200	2	87	482	338301	2	92	75	313202
2	82	120	386000	2	87	482	338302	2	92	73	314100
2	82	120	387000	2	87	98	339000	2	92	73	314200
2	82	121	388000	2	87	94	341000	2	92	73	314299
2	82	121	389100	2	87	94	342000	2	93	76	305000
2	82	121	389200	2	87	99	343001	2	93	78	306000
2	82	122	390100	2	87	99	343002	2	93	81	307100
2	82	122	390200	2	87	99	343003	2	93	77	307201

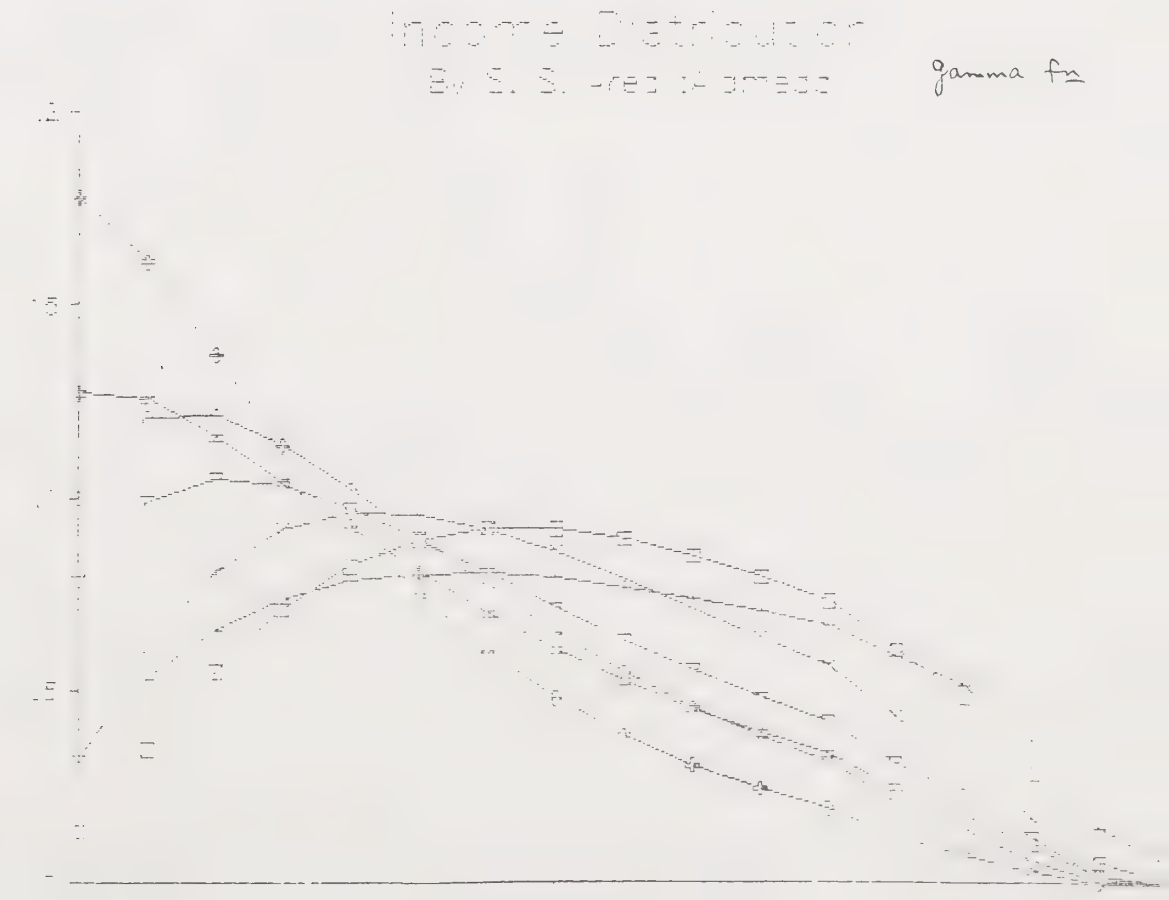
COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT	COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT	COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT
2	93	76	307202	8	99	61	250800	9	104	456	153004
2	93	77	307203	8	99	61	250899	9	104	42	153100
2	93	79	308000	8	99	60	250900	9	104	42	153200
2	93	79	355101	8	99	60	251000	9	104	42	153300
2	94	80	301000	8	99	59	251100	9	105	41	151400
2	94	80	302000	8	99	59	251200	9	105	454	151501
2	94	82	303100	8	99	59	251300	9	105	454	151502
2	94	82	303200	8	99	63	251400	9	105	453	151600
2	94	82	304000	8	99	60	251500	9	105	39	151700
8	95	70	252902	8	99	60	251600	9	105	39	151800
8	95	71	252903	8	99	60	251701	9	105	40	151900
8	95	70	252904	8	99	60	251702	9	105	40	152000
8	95	475	252905	8	99	62	251801	9	105	38	152100
8	95	474	253000	8	99	62	251802	9	105	37	152200
8	95	72	253101	8	99	63	251901	9	105	37	152300
8	95	474	253102	8	99	464	251902	9	105	37	152400
8	95	474	253103	8	99	464	251903	9	105	35	152501
8	95	72	253201	4	100	54	200100	9	105	35	152502
8	95	72	253202	4	100	54	200200	9	105	35	152600
8	95	72	253203	4	100	462	200300	9	106	449	151000
8	95	69	253300	4	100	461	200400	9	106	449	151100
8	95	69	253400	4	100	460	200500	9	106	33	151201
8	96	64	252200	4	100	49	200600	9	106	33	151202
8	96	469	252301	4	100	459	200700	9	106	33	151301
8	96	473	252302	4	100	53	200800	9	106	450	151302
8	96	473	252303	4	100	55	200900	9	106	450	151303
8	96	65	252304	4	100	463	201000	9	106	33	151304
8	96	468	252401	4	100	53	201100	9	107	446	150601
8	96	468	252402	4	100	51	201200	9	107	446	150602
8	96	66	252501	4	100	51	201300	9	107	32	150603
8	96	66	252502	4	100	52	201400	9	107	32	150604
8	96	470	252604	4	101	50	201500	9	107	31	150700
8	96	470	252605	4	101	50	201600	9	107	448	150800
8	96	471	252606	4	101	48	201700	9	107	447	150900
8	96	66	252607	4	101	48	201800	9	108	34	150100
8	96	471	252608	4	101	47	201900	9	108	34	150200
8	96	471	252609	4	101	47	202000	9	108	451	150301
8	96	472	252701	9	102	44	153701	9	108	451	150302
8	96	65	252702	9	102	44	153702	9	108	452	150400
8	96	67	252800	9	102	458	153800	9	108	452	150500
8	97	68	253500	9	102	45	153900	3	109	22	113000
8	98	56	252000	9	102	45	154000	3	109	24	132100
8	98	467	252101	9	102	46	154100	3	109	445	132200
8	98	56	252102	9	102	46	154200	3	109	23	133000
8	98	56	252199	9	102	44	154300	3	110	29	101100
8	99	465	250101	9	103	43	153401	3	110	29	101200
8	99	465	250102	9	103	43	153402	3	110	30	102100
8	99	58	250200	9	103	43	153500	3	110	30	102200
8	99	58	250300	9	103	43	153600	3	110	25	103100
8	99	58	250400	9	104	457	152700	3	110	28	103200
8	99	58	250501	9	104	36	152800	3	110	26	104100
8	99	58	250502	9	104	36	152901	3	110	27	104200
8	99	57	250601	9	104	36	152902	3	110	17	104300
8	99	57	250602	9	104	455	153001	3	110	17	105000
8	99	466	250701	9	104	455	153002	3	111	16	106000
8	99	466	250702	9	104	455	153003	3	111	18	107000

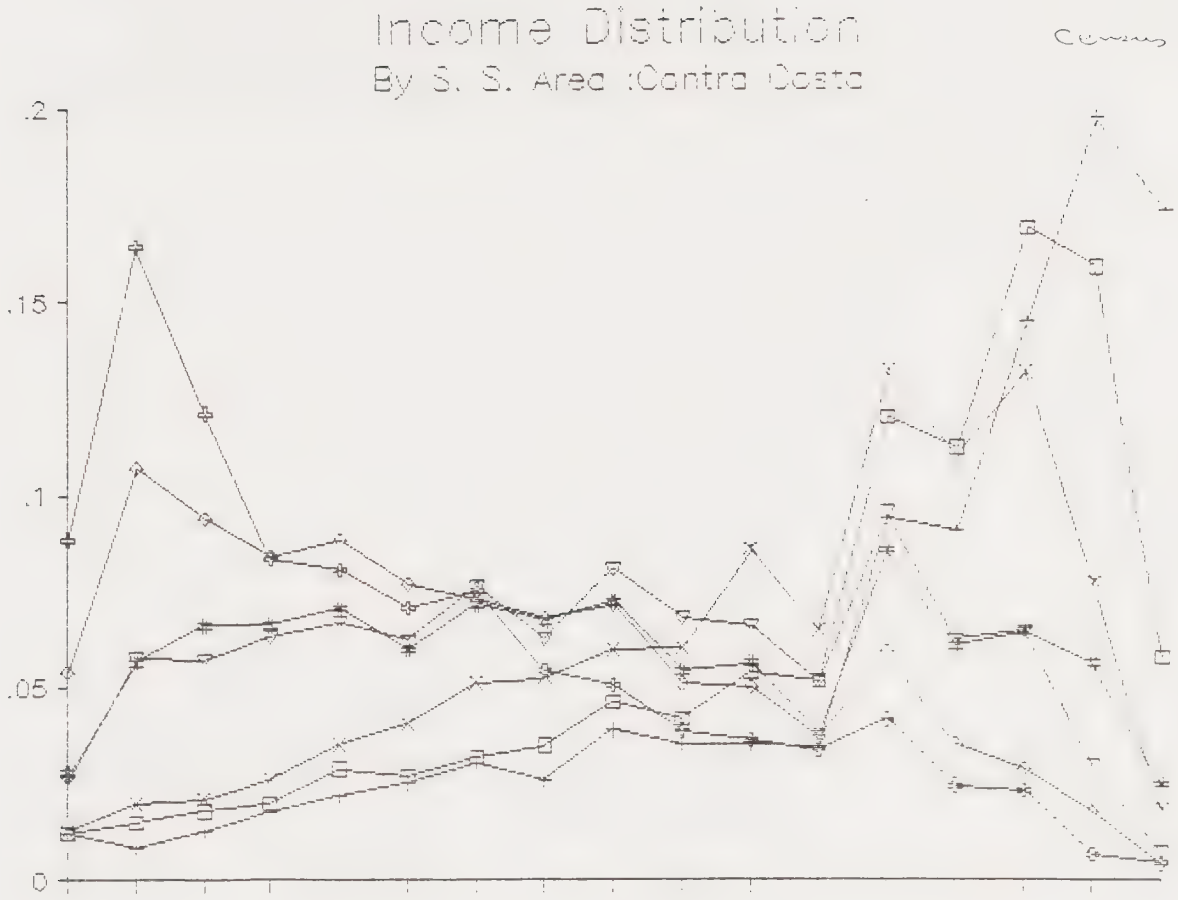
COUNTY	SUPER ZONE	550 ZONE	CENSUS TRACT
3	111	444	108100
3	111	19	108200
3	111	12	109000
3	111	15	110100
3	111	443	110200
3	111	13	111000
3	111	14	112100
3	111	14	112200
3	112	10	114100
3	112	10	114200
3	112	20	115000
3	112	11	116000
3	112	11	117000
3	112	21	118100
3	112	21	118200
3	112	21	119100
3	113	9	119200
3	113	8	120000
3	113	6	121100
3	113	6	121200
3	113	6	122000
3	114	3	123000
3	114	4	124100
3	114	3	124200
3	114	4	125000
3	114	5	126100
3	114	442	126200
3	114	5	127000
3	114	7	128100
3	114	441	128200
3	114	1	129000
3	114	2	130200

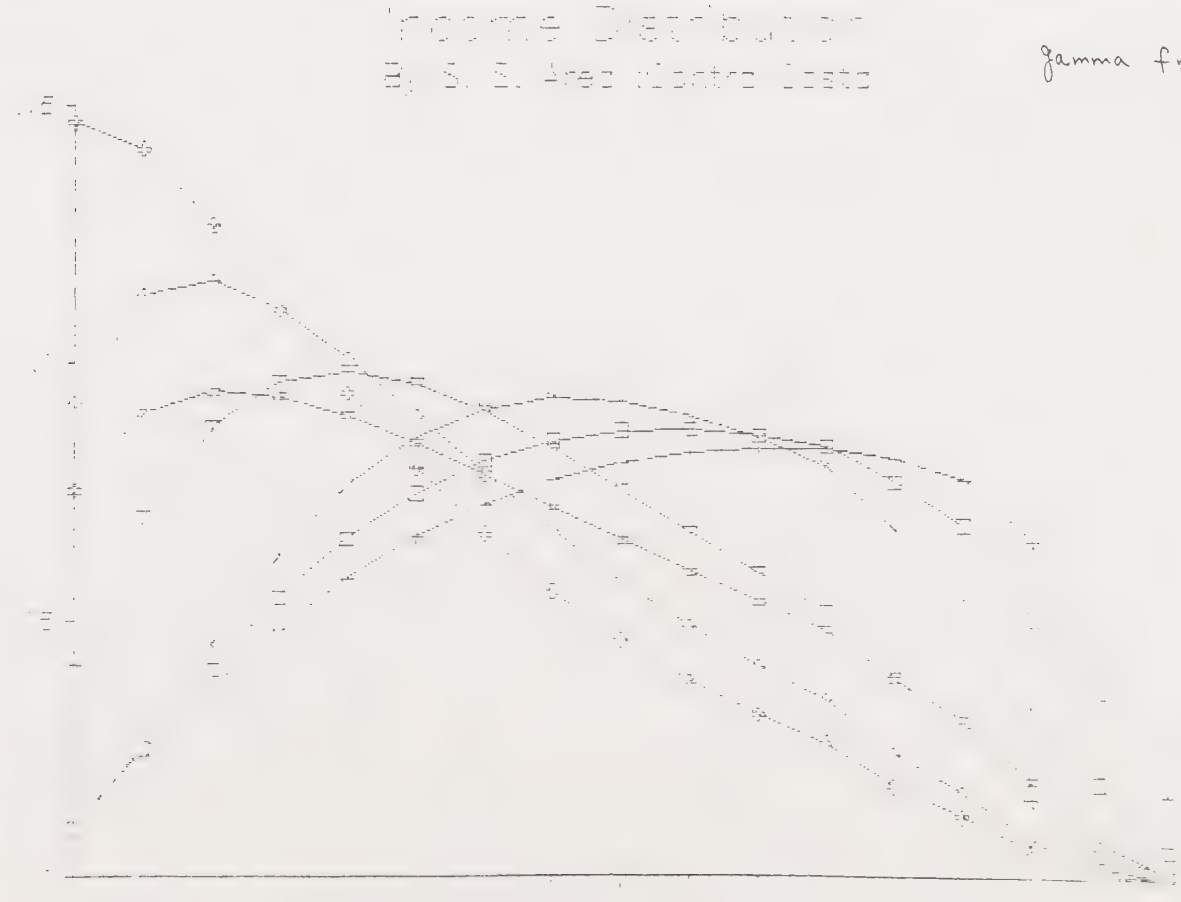
APPENDIX C

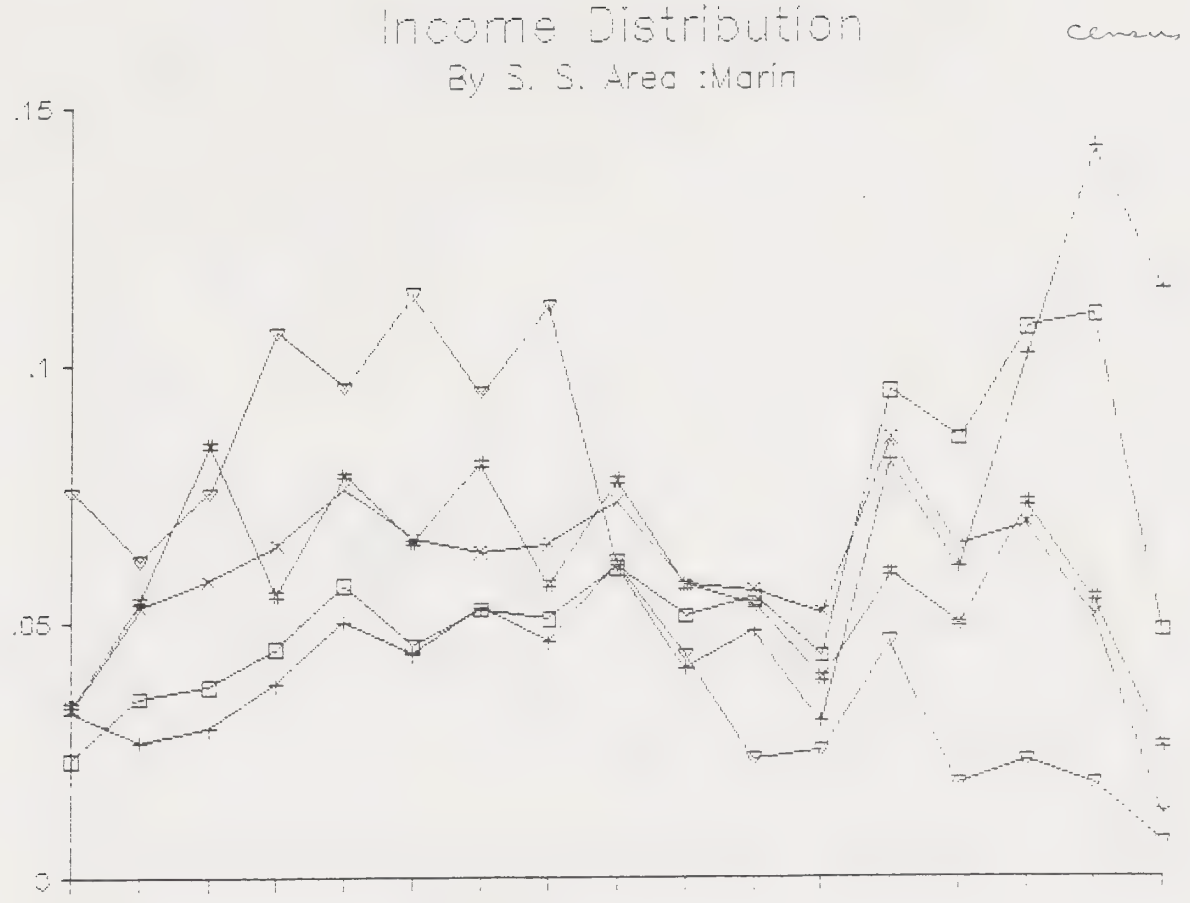
Plottings of Income Distribution by County

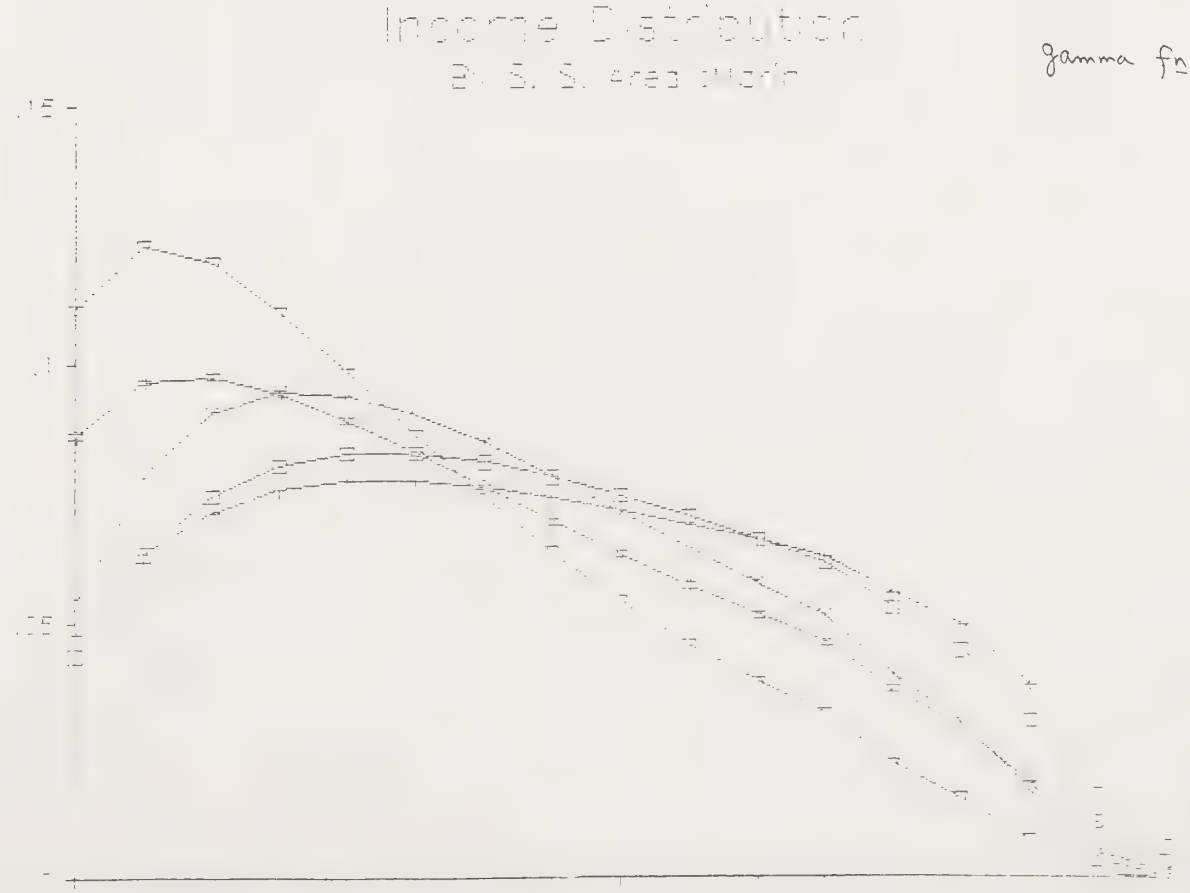

Income Distribution
By S. S. Area :Alameda
.25
.2
.15
.1
.05
0


Income Distribution
By S. S. Area :Alameda


Income Distribution
By S. S. Area :Contra Costa
.2
.15
.1
.05
0

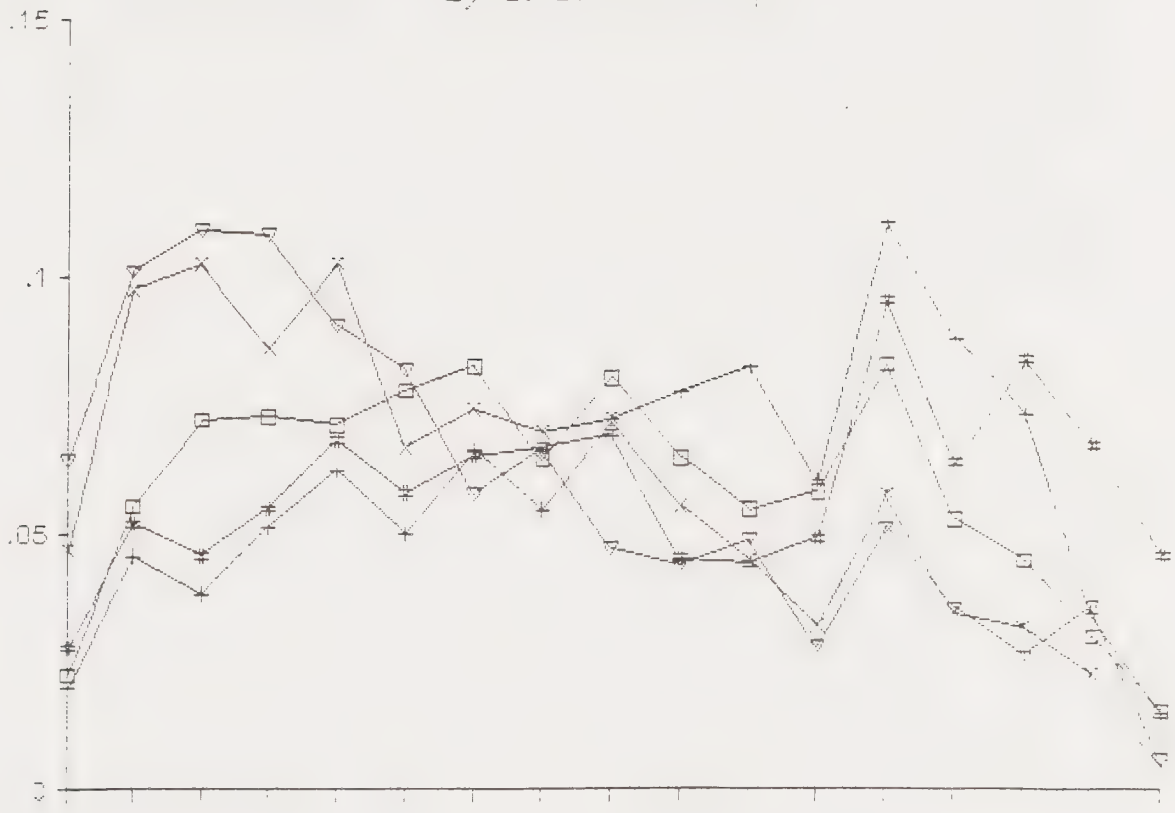

Income Distribution
By S. S. Area :Contra Costa


Income Distribution
By S. S. Area :Marin
census
.15
.1
.05
0


Income Distribution
gamma fn

Income Distribution

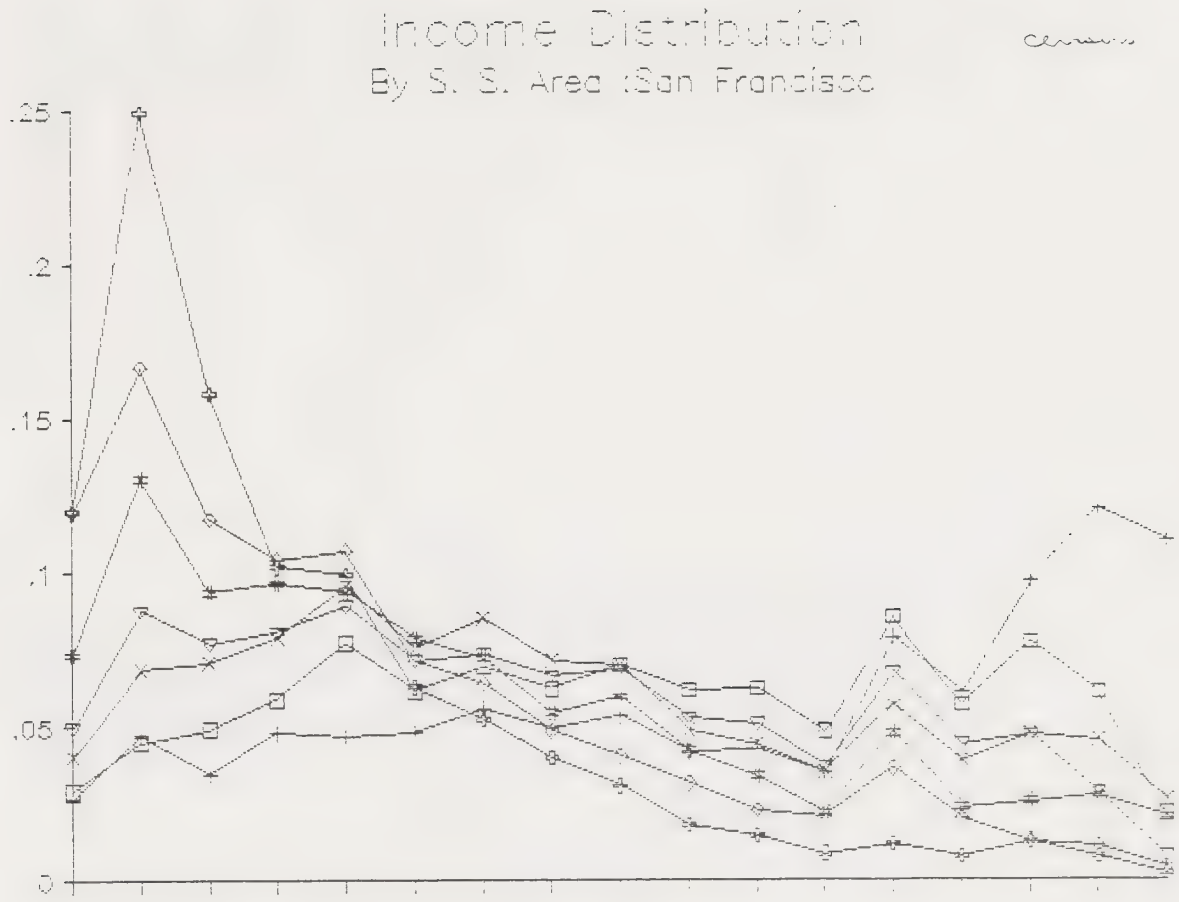
By S. S. Area :Napa

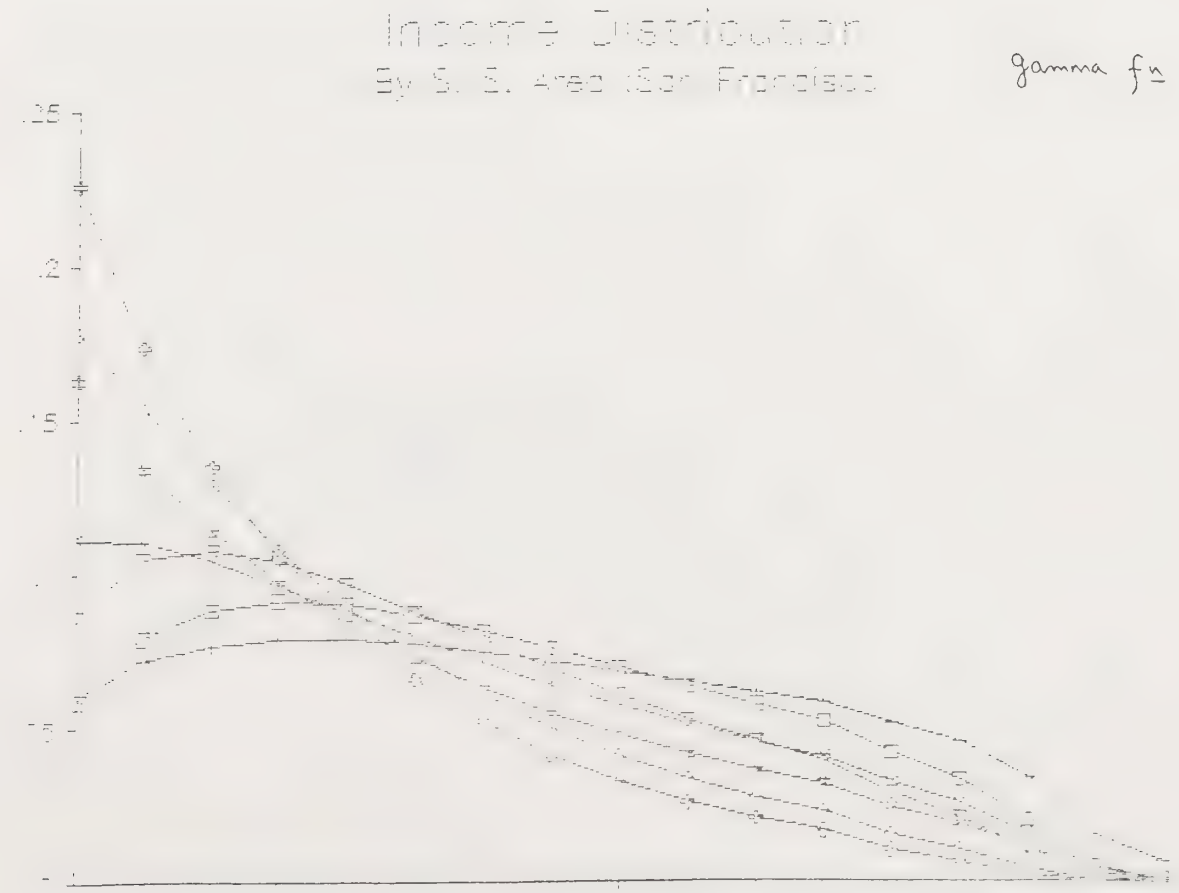


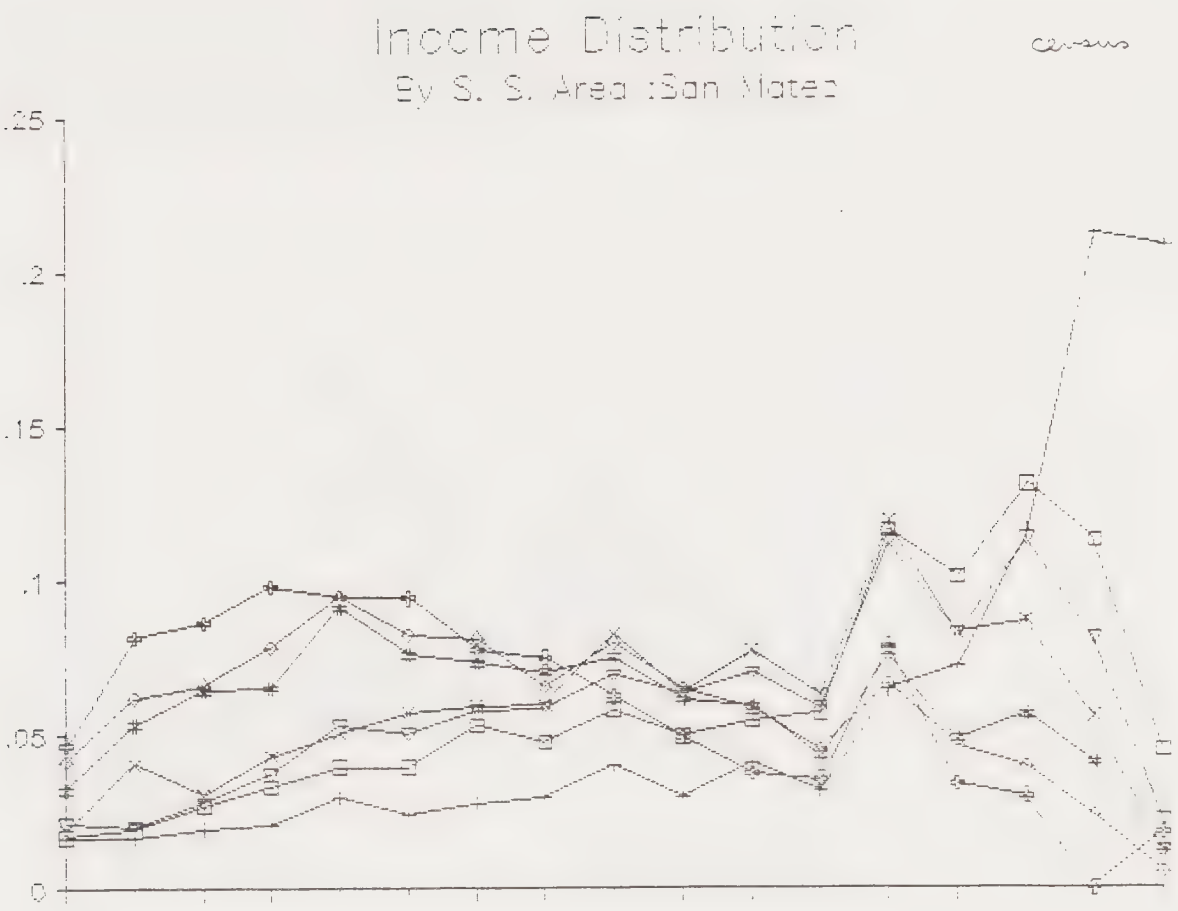
Income Distribution

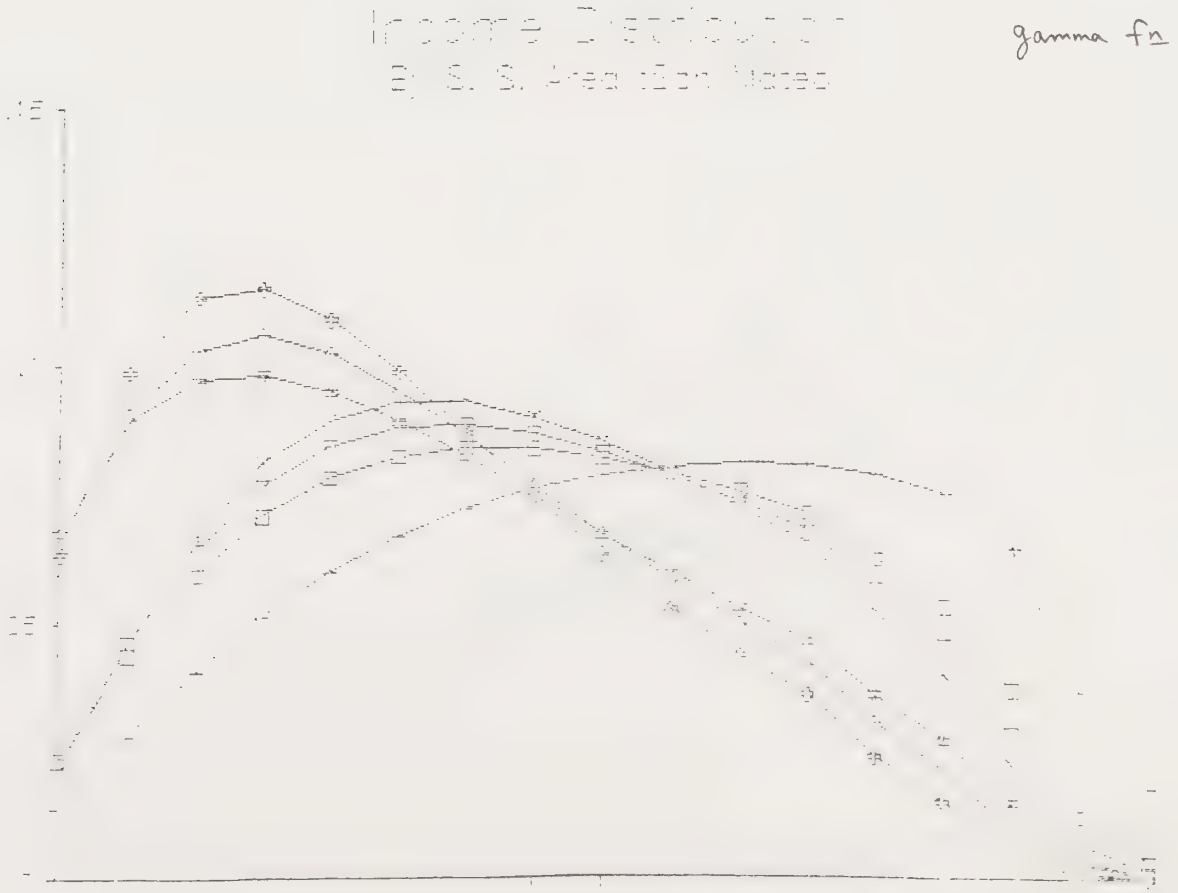
By S. S. Area :Napa

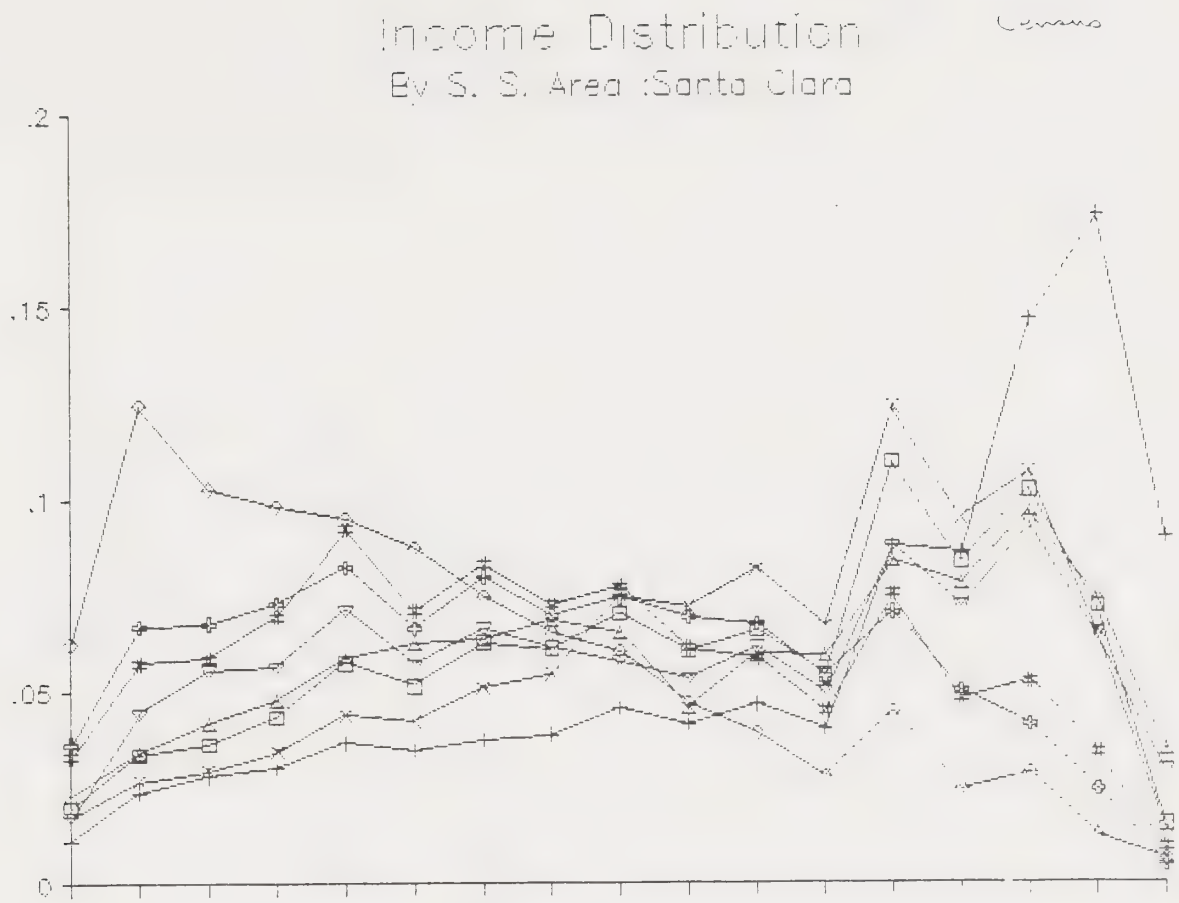
gamma fn

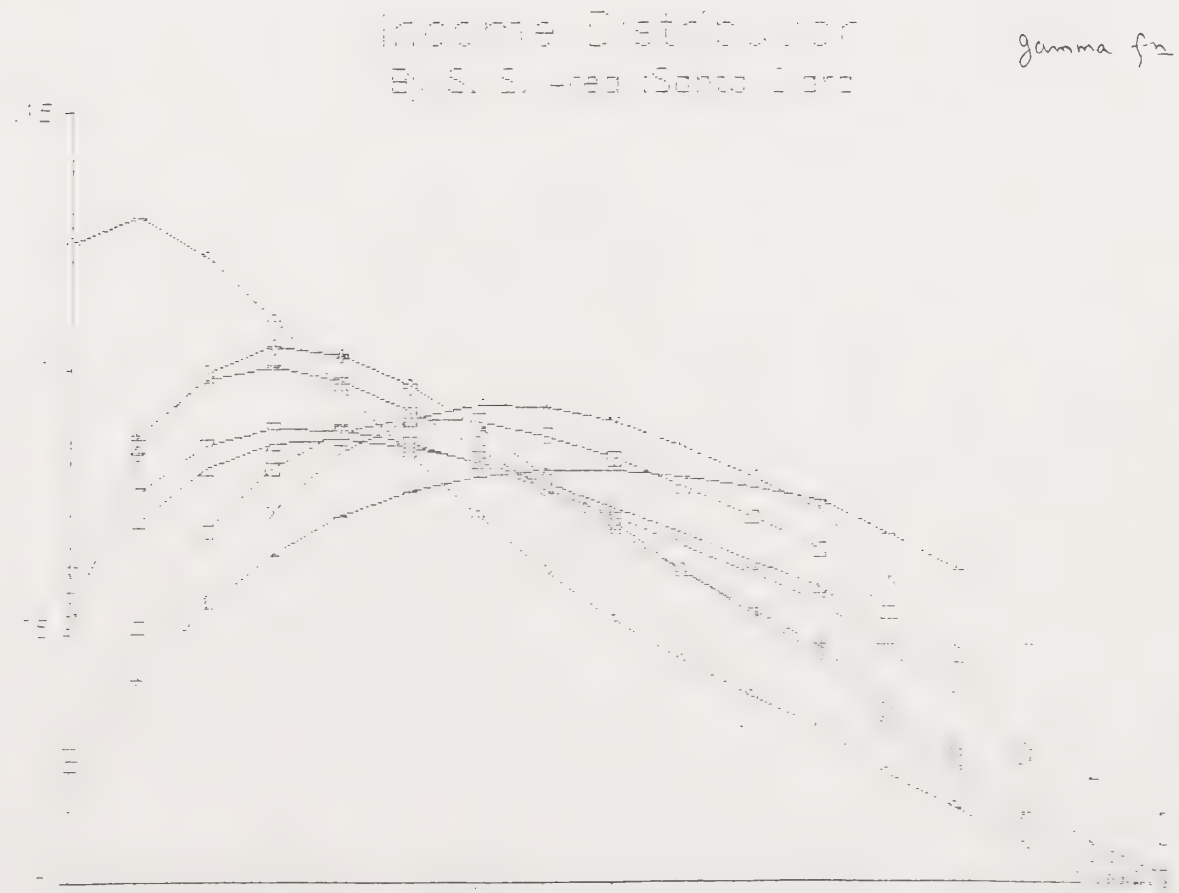

Income Distribution
By S. S. Area :San Francisco
.25
.2
.15
.1
.05
0


Income Distribution
By S. S. Area :San Francisco
gamma fn


Income Distribution
By S. S. Area :San Mateo
census
.25
.2
.15
.1
.05
0

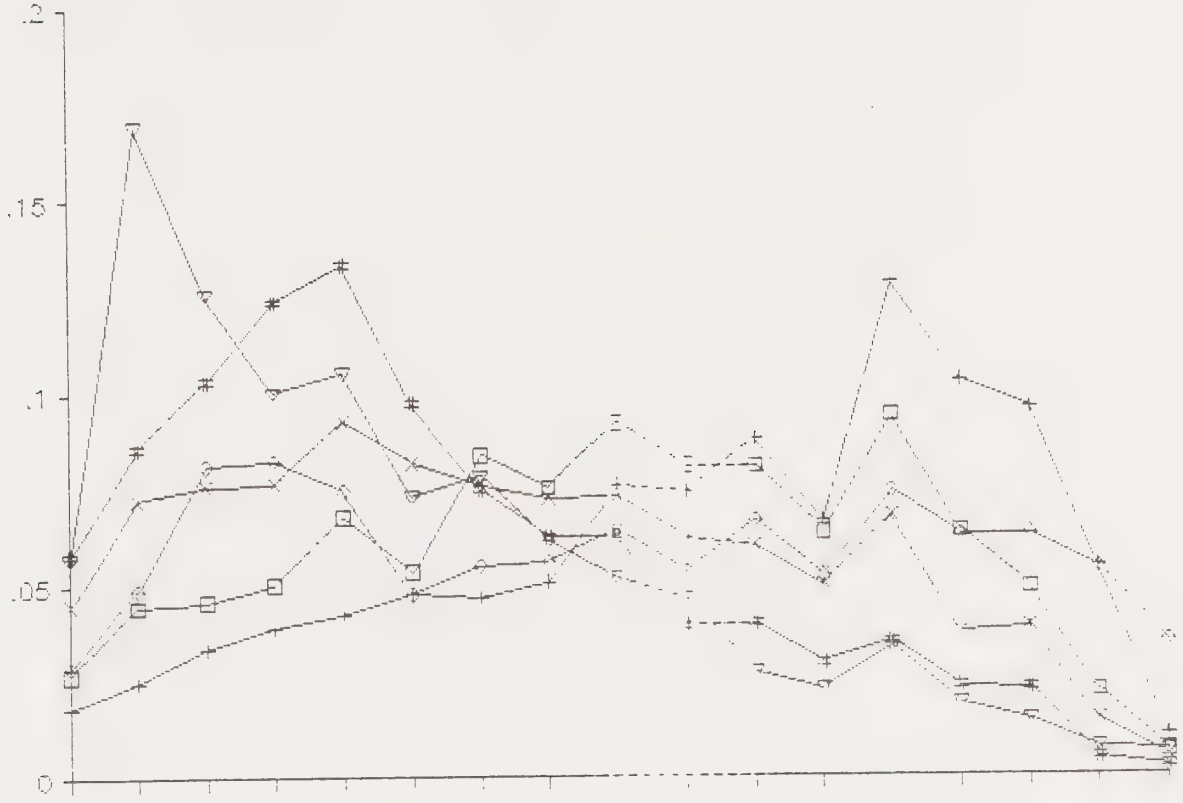

gamma fn


Income Distribution
By S. S. Area :Santa Clara
.2
.15
.1
.05
0


gamma fn

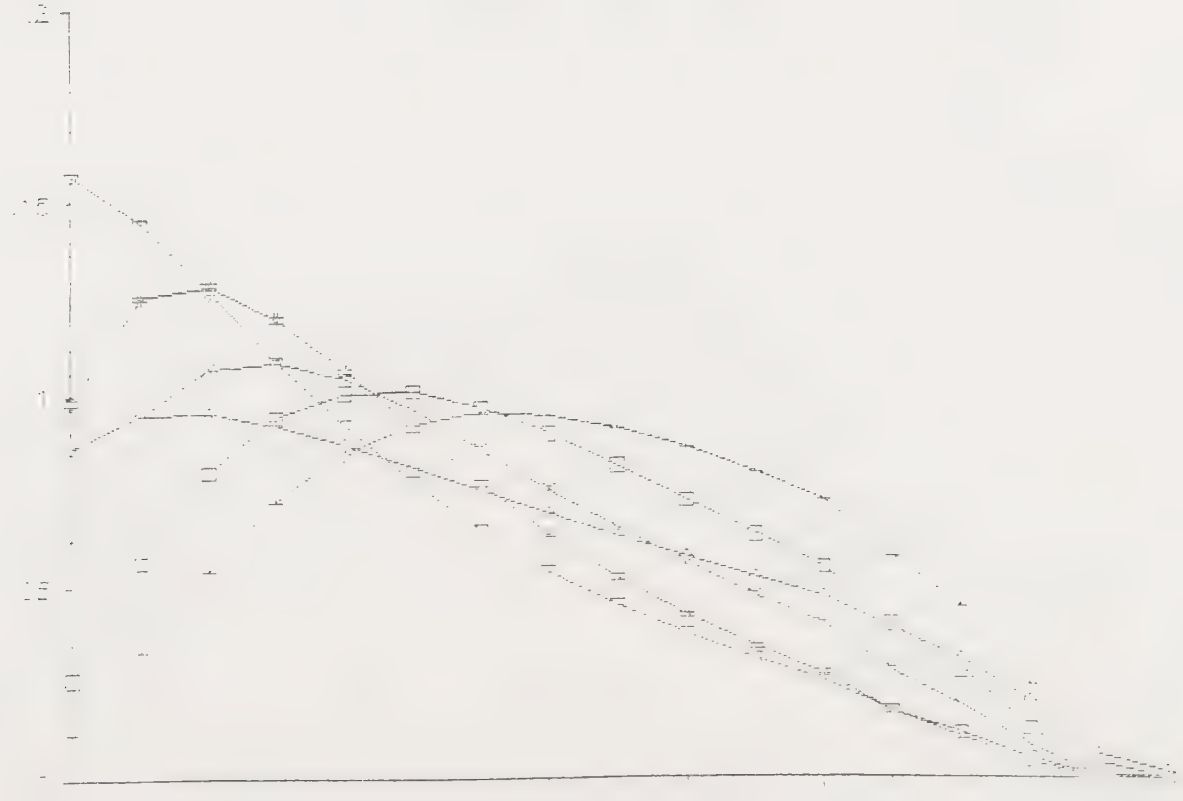
census

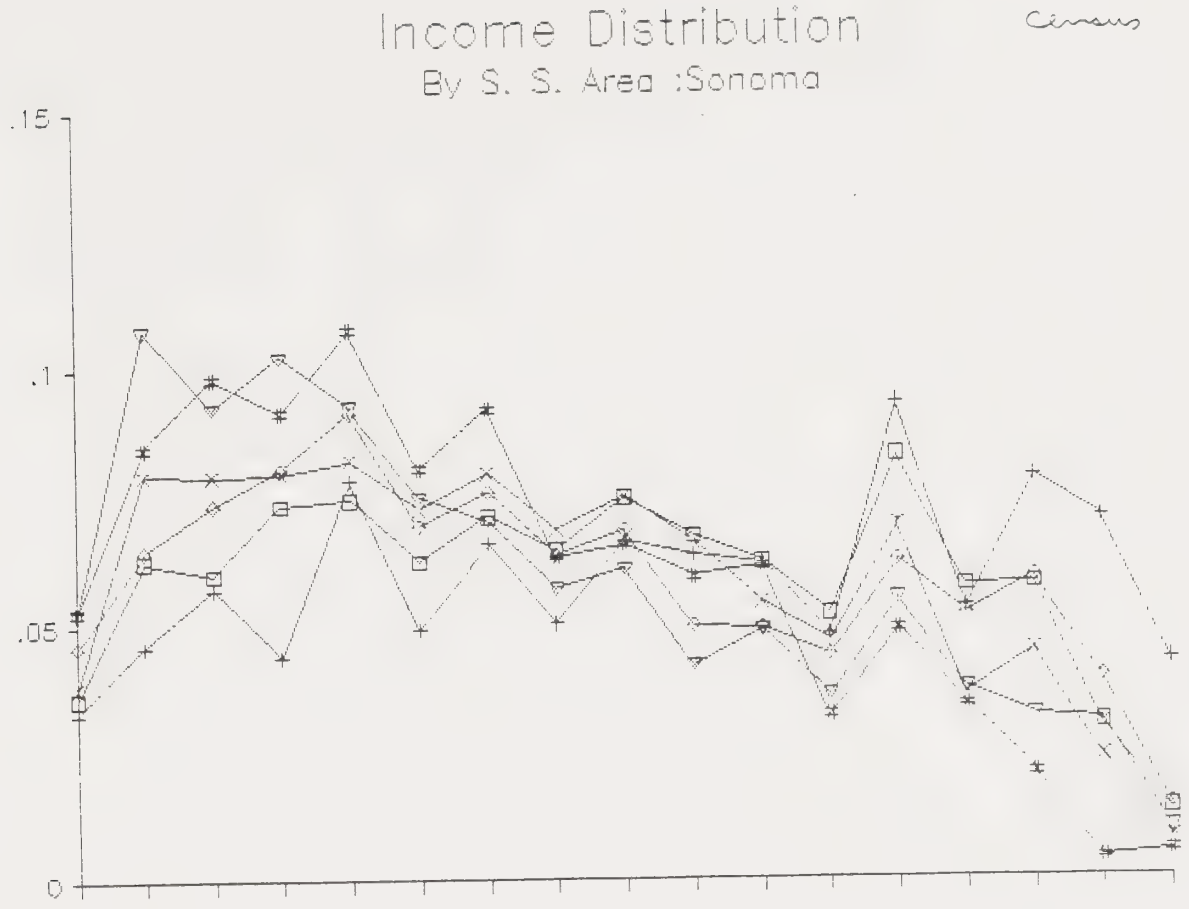
Income Distribution
By S. S. Area :Solano

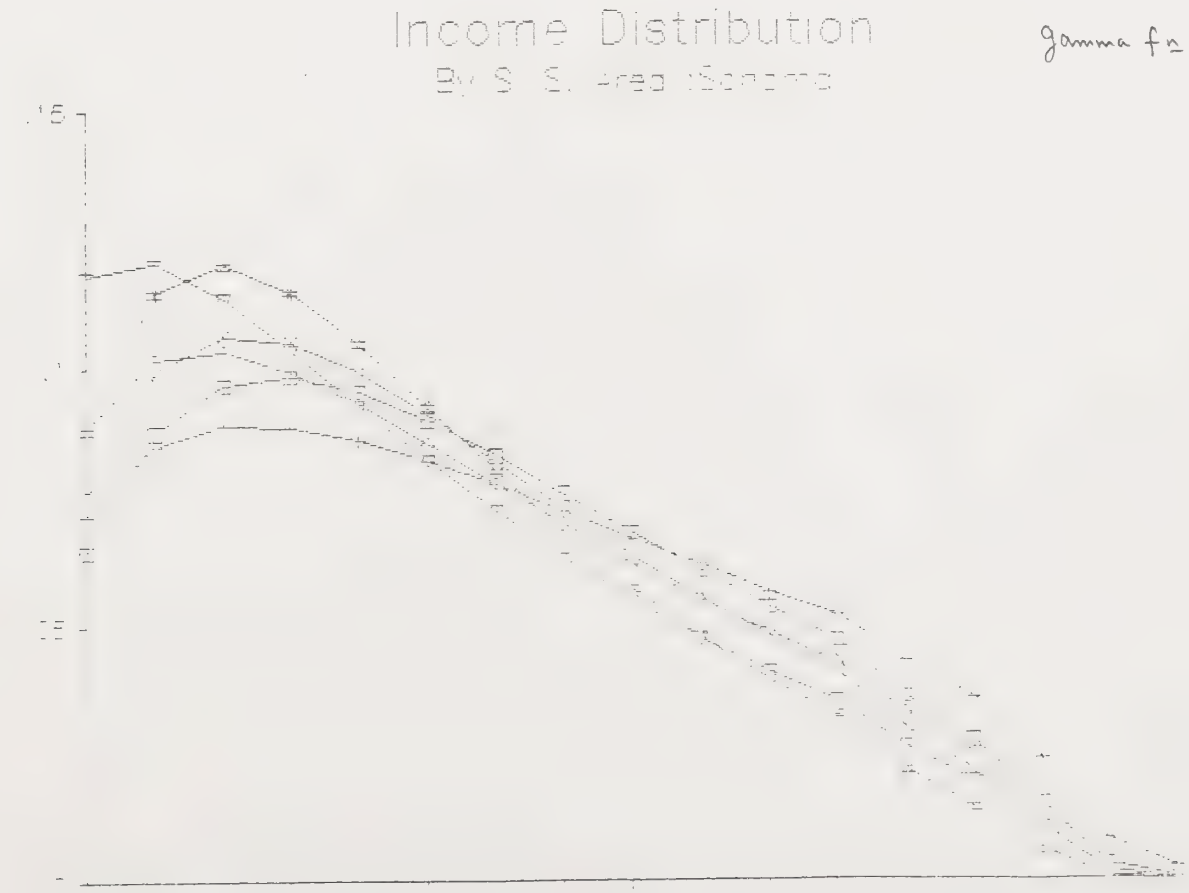


gamma fn

Income Distribution
By S. S. Area :Solano




Income Distribution
By S. S. Area :Sonoma
census
.15
.1
.05
0


Income Distribution
gamma fn

APPENDIX D

FORTRAN Source Listing of Adjustment Procedure

```
      subroutine norm(m,n,a,d,td,zd,b,c,tb,zb,star)
c*****************************************************************
c*                                                               *
c*          R A S                                                *
c*                                                               *
c*****************************************************************
c                                                                 *
c       A general subroutine to RAS a matrix.                     *
c       All input, output matrix, target vectors, and number of   *
c       row and column should be in the increment.                *
c                                                                 *
c*****************************************************************
c*      variables definition :
c*
c*      m - number of rows (number of subarea)
c*      n - number of columns (number of projection period)
c*      tb(m) - base vector of row sum
c*      td(m) - target vector of row sum
c*      zb(n) - base vector of column sum
c*      zd(n) - target vector of column sum
c*      a(m,n) - starting matrix (input)
c*      b(m,n) - working matrix
c*      c(m,n) - working matrix
c*      d(m,n) - final RASed matrix (output)
c*
c*****************************************************************
c
      real a(m,n),b(m,n),c(m,n),d(m,n)
      real tb(m),zb(n),td(m),zd(n)
      character*1 star(m)
c     treat negative (decrease) cells as zero
      do 10 i=1,m
      star(i)=1h
      do 10 j=1,n
      b(i,j)=a(i,j)
      if(a(i,j).lt.0.0) then
              b(i,j)=0.0
              star(i)=1h*
      end if
10    continue
c     iterate for 10 times.
      do 20 l=1,10
c     initialize temp totals.
      do 30 i=1,m
30    tb(i)=0.0
      do 40 j=1,n
40    zb(j)=0.0
```

```
c       substitute matrix (update) except for the first iteration.
        if(l.gt.1) then
           do 50 i=1,m
           do 50 j=1,n
50         b(i,j)=d(i,j)
        end if
c       to find the new non-negative row totals.
        do 55 i=1,m
        do 55 j=1,n
55      tb(i)=tb(i)+b(i,j)

c       row-wise adjustment.
        do 60 i=1,m
        do 60 j=1,n
        c(i,j)=0.0
        if(tb(i).gt.0.) c(i,j)=td(i)/tb(i)*b(i,j)
60      continue
c       prepare new column sum after row-wise adjustment.
        do 65 i=1,m
        do 65 j=1,n
65      zb(j)=zb(j)+c(i,j)
c       column-wise adjustment.
        do 70 i=1,m
        do 70 j=1,n
        d(i,j)=0.0
        if(zb(j).gt.0.0) d(i,j)=zd(j)/zb(j)*c(i,j)
70      continue
20      continue
        return
        end
```